LECTURES

ON THE THEORY AND GENERAL

PREVENTION AND CONTROL OF INFECTIOUS DISEASES.

BY JAS. B. RUSSELL, B.A., M.D.,
MEDICAL OFFICER OF HEALTH.

AND ON

AIR, WATER SUPPLY, SEWAGE DISPOSAL, AND FOOD.

BY WILLIAM WALLACE, PH.D., F.C.S.,
CITY ANALYST,

DELIVERED UNDER THE
AUSPICES OF THE LORD PROVOST, MAGISTRATES, AND COUNCIL
OF THE CITY OF GLASGOW, AND NOW
PUBLISHED BY THEM.

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PREFATORY NOTE.

THESE Lectures were delivered at the instance and under the auspices of the Lord Provost, Magistrates, and Town Council of Glasgow, in the Corporation Galleries, and are now printed in accordance with the following Minute of the Committee of Health, dated 30th December, 1878, and confirmed by the Town Council, 18th January, 1879:—

"On the motion of Councillor Mowat, seconded by Coun-"cillor Mathieson, the Committee agreed to record in their "Minutes their thanks to Dr. Russell, Medical Officer of the "City, and Dr. Wallace, City Analyst, for the interesting and "useful course of Lectures on Public Health recently delivered "by them in the Corporation Galleries, and to recommend "that, with consent of these gentlemen, the Lectures should "be printed for distribution to the Magistrates and Council, "and published at a nominal charge."

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N.B.—The Plates are reduced from Diagrams executed in the Sanitary Office, specially for these Lectures. Plates I., II., and IV. were photo-lithographed from the Originals by Inspector Dobson. Plates II.*a*, III., V., and VI. were reduced from the Originals by Mr. Fincke, Draughtsman in the Department, the Originals being in both cases drawn by him.

LECTURES BY DR. RUSSELL.

LECTURE I.

ON THE THEORY OF INFECTIOUS DISEASE.

(Nov. 26th, 1878. Bailie Scott in the Chair.)

LADIES AND GENTLEMEN,

When I was asked to give a few lectures on some subject connected with public health, I decided that that subject should be "The Theory and General Prevention and Control of Infectious Diseases," for various reasons. In the first place, Infectious Diseases contribute very largely to the total amount of disease and death in all communities, but especially in large cities. I cannot find words better fitted to impress you with their importance than those of Dr. Farr, who says:—"Diseases of this class distinguish one country from another—one year from another; they have formed epochs in chronology; and, as Niebuhr has shown, have influenced not only the fate of cities, such as Athens and Florence, but of empires; they decimate armies, disable fleets; they take the lives of criminals that justice has not condemned; they redouble the dangers of crowded hospitals; they infest the habitations of the poor, and strike the artizan in his strength down from comfort into helpless poverty; they carry away the infant from its mother's breast, and the old

man at the end of life; but their direst eruptions are excessively fatal to men in the prime and vigour of age." Yet, being all this, they are "preventable." Everybody now speaks of them as distinctively the "preventable diseases," although the old term "plague" carries us back to the time when they were regarded as the blows or punitive inflictions of some supernal power, and as such scarcely to be thought of as a subject of investigation, as if they could by any possibility be brought within the range of the ordinary laws of causation. So far is this from being true that I believe (and this is a third reason for my choice of a subject), when closely scrutinized in their rudiments and mode of origin and distribution, infectious diseases are not phenomenal and odd, but essentially typical of widely acting causes of disease and death operative always and in all places. This being my belief, the fourth and perhaps the most important attraction which this subject has for me is this, that a correct appreciation of the principles which govern the spread of infectious diseases, and a knowledge of which is necessary for their general control and prevention, is essential for the intelligent and efficient prosecution of all sanitary work. In fact, in preventing and controlling those diseases we are not only undertaking a labour whose results will be of the most obvious and unquestionable kind, but we are adopting the best means to elevate and improve the general health of the people throughout its entire area; we are working at the foundation of the fabric of public health.

The thesis which I ask you to join me to-night in thinking out is this—that normal healthy life consists essentially in a process of infection of the *media* in which it exists; that certain laws of nature must be observed, or this simple or non-specific infection inevitably begets disease; that specific

infection flourishes or is prevented just in proportion as these laws of nature are observed or violated, and that consequently in the broadest and most practical sense, the conditions which ordinarily promote general health are precisely those which limit the risk of infectious disease attacking the individual and becoming epidemic in the community.

In supporting this thesis I do not intend to trouble you with refinements about *infection* and *contagion*, because these are of no practical significance—it is questionable if they exist at all as real distinctions. Nor in speaking of the theory of infectious disease do I propose to enter upon discussions as to germ theories or glandular theories, or any other theories the correctness or incorrectness of which do not affect the soundness of the purely practical principles of sanitary work. Happily they have, by universal consent, a common basis of fact upon which we can work without troubling ourselves with the merits of their details. Nor yet shall I raise the question of the origin of these diseases, which is really but a subdivision of the great question of spontaneous generation. As we now find them, they breed true, and like the origin of Animals and Vegetables, in these latter days the beginning of Small-pox, Typhus, and other like diseases has only a remote historic interest. Their precise parentage and pedigree may not be *quite* so easily traced; but it none the less certainly exists, and spontaneous generation is only a bridge hastily thrown over the gaps left by our own ignorance. My aims are purely practical. If we did not make a firm resolve to follow this clue, we might in the study of infectious diseases wander over all creation, and dip into every science. Thus to expatiate would be very interesting and not altogether uninstructive, but tell me of what use for the guidance of a medical officer of health or a sanitary inspector face to face

with the momentous details of his daily work, is such an oracular deliverance as this which I extract from the usually prosaic pages of the Scotch Census Report (vol. II., p. xciii.): "From recent researches there can be no doubt that the whole atmospheric phenomena on the earth's surface, its weather, its storms, its magnetism, and electricity are dependent on the condition of the sun's chromosphere; and no one can doubt that the health, sickness, and rate of mortality among the inhabiters of the earth's surface are under a like influence." Ladies and Gentlemen, this may be all very true, but I venture to say, that if the "sun's chromosphere" influences our health, it is through the nuisances which surround our own doors, and I prefer to leave the "chromosphere" alone, and to study the nuisances! You remember what Milton tells us—

> "That not to know at large of things remote
> From use, obscure and subtle, but to know
> That which before us lies in daily life,
> Is the prime wisdom."

I am therefore chiefly anxious not to distract your attention from practical issues, or load your memory with isolated facts, but to deal as much as possible with broad principles, to lead you into a true method of thinking about infectious disease when it may chance to invade your own social circle, or become the occasion of public interference and procedure on the part of those who are responsible for the health of the community in this regard. The details of every kind of work must be carried out in accordance with predetermined principles, otherwise it becomes merely the spasmodic action of caprice, full of inconsistencies, irritating to those who have to be directed and governed by it, and above all, totally unproductive of good results.

As my remarks have a strictly local reference, and also

because we must not attempt too much in this short series of lectures, I shall confine my special observations to those infectious diseases which are most common and fatal in Glasgow, viz.: the fevers, small-pox, scarlet fever, measles, hooping-cough, diphtheria, and also cholera, although fortunately the present generation of the inhabitants has seen little or nothing of it. To give precision to our impressions of the gravity of these diseases to us as a community, I may tell you that in the 10 years 1861-1870, they caused 26,398 deaths, or a fifth part of the total death-rate (6 out of 30 per 1000 living); in the 5 years 1871-1875, they caused 12,987 deaths, or a sixth part of the total death-rate (5 out of 30 per 1000 living); and in the last 2 years 1876-7, they caused 3005 deaths, or rather more than one-ninth of the total death-rate (2·7 out of 25 per 1000 living). This is a total of 42,390 deaths in 17 years, or an average of nearly 2500 per annum.

An *infectious* disease is one whose general habit and constant tendency it is to attack, or prevail among, great numbers of the people. Such a disease is said to be *sporadic* when as yet it exists only here and there in scattered, isolated cases, and *epidemic* when it has actually attacked a large proportion of the population. But there are diseases which may affect many individuals at the same time, and may even arise from one widely acting cause, and which yet are not, properly speaking, epidemic. The dry, cold winds of March may prostrate a number of individuals with bronchitis, pneumonia and pleurisy, yet these diseases are not then epidemic in the strict technical sense, though they are so etymologically. There is involved in the term, besides the idea of general prevalence, that of lateral transmissibility, the power of propagation from one person who is diseased to another, side by side, who is healthy. This property is

expressed in the generic term applied to the whole class of truly epidemic diseases, viz., *Zymotic*. But the adjective, Zymotic, not only involves the idea of transmissibility, but also includes a theory as to the mode of transmission. It implies an action upon the healthy of something which passes to them from the diseased, and acts like a ferment—like yeast. If you take a solution of sugar in water, and add to it a few particles of yeast, in the course of a few hours the temperature of the liquid rises, bubbles of carbonic acid are given off; in short, the process of fermentation is in full swing, and the yeast plant multiplies, *i.e.*, the particles which infected the liquid with the fermentive process are increased in number, and consequently may be employed to establish the infection in fresh solutions. But however interesting this theory may be, and however apt as an illustration even by analogy of the process of transmission of epidemic disease, I shall not ask you to carry away in your minds more than this from the illustration; that a material something, particles having dimensions, passes from the diseased to the healthy, and there sets up the same disease.

Let us now for a moment lay aside the idea of disease, and consider the relations of normal healthy life to the medium in which life is maintained, and again the relations of units of life to each other, established through the medium in which those units of life are maintained. Do living things produce any changes upon the area of inorganic elements by which they are surrounded? and, if so, are those changes of such a nature that the proximity of one living thing to another is ever a matter of indifference? or are they of such a nature as to open up paths of relationship, and to develop possibilities of influence which carelessness and ignorance may suffer to grow into conditions which will produce disease?

We have seen that particles of yeast, which are living vegetable cells, dropped into a solution of sugar and water, very soon produce changes in that solution which is the medium in which they live. Particles of sand dropped into the solution would simply sink to the bottom of the vessel, agitating the fluid for a few moments but leaving it in composition unchanged. In like manner, if I removed a stone from the street and set it down in this room, it would, being colder than the air of this room, establish round about it little eddies and currents of air, until, by exchange of heat, the stone and the air had attained the same temperature, and no alteration, excepting such as was required to maintain this equilibrium, would be effected either in the stone or in the air. But the relations between each individual among my audience and the air of this room are very different. From the instant when the first person entered this room, a series of changes in the constitution and component parts of the surrounding atmosphere was set agoing, and the combined products of certain of your vital functions are accumulating within the space bounded by the walls of this apartment. Nor are these products mere theoretical figments. They could be demonstrated to your eyes by chemical processes, and by the aid of the microscope, and are so real, so material, and so characteristic that after you leave it would be easy, by those means, to prove that you had been present. The yeast plant and the man are illustrations derived from the simplest form of vegetable and the most complex form of animal life, of a power which is the common characteristic of all life—that of changing the constitution and component parts of the dead, inorganic media which surround and abut upon it.

Having answered my first question—Do living things

produce any change upon the inorganic elements by which they are surrounded?—in the affirmative, let us now take up the second—Are these changes a matter of indifference to living things surrounded by the same media, or are they such as to open up paths of relationship and to develop possibilities of influence exercised by one unit of life upon another? The idea of indifference may be summarily dismissed. The process of fermentation, which is the name given to the vital action of the yeast plant, if allowed to advance in a limited quantity of the saccharine fluid, ends in the production of a fluid which will not sustain the life of the yeast plant; and the presence of this audience in this hall, without renewal of the air enclosed by its walls, would end in the production of an atmosphere which would not sustain animal life. But long before this point is reached, supposing the air to be imperfectly renewed, your individual sensations would proclaim the fact that through the medium of the air a common deleterious influence was being generated; and this would be your joint experience, whatever your condition as to health individually might be. Permit me to assume that some of you are not in this condition of perfect health; and let me first suggest the presence of a few cases of bronchitis or mild catarrh—a supposition which in this climate at this season of the year is not very violent or unlikely to be correct. What then? The presence of persons so affected would not in the slightest increase the risk which those who are present and not yet affected run of being attacked by bronchitis or catarrh before the end of the week. But permit me still further to assume that some one is present who is suffering from typhus, or who is convalescent from scarlet fever: then, undoubtedly, the presence of such a person would render it highly probable that within the

next fortnight the healthy individuals who sat next to the hypothetical unhealthy individual would be stricken with typhus or scarlet fever. Here then we have two kinds of relationship between, and mutual influence exercised upon, the units of life, comprising a company of men living for a short space of time in one medium—the atmosphere of an apartment. The question is, What established the morbific relationship between the healthy and the unhealthy? It is not the creation, the calling into being, of a relationship which does not exist between persons in proximity and in health, nor is it even a relationship begotten of disease in general. It *must* be the introduction into this relationship of some new element, something which does not belong to the state of health nor yet to the state of disease in general. I say "must be," because we have got beyond the stage of belief in an "evil eye," and I apprehend that even the resources of spiritualism are not potent enough to produce typhus or scarlet fever by any immaterial "force!"

Let us now enquire in more detail, although still in a very general way, into the nature of the changes produced by man upon the *media* in and upon which he lives, while in a state of health, and the paths of influence of one man upon another opened up by these changes. Having obtained some certain knowledge of the relationships belonging essentially to healthy life, we shall be able to answer the further and most interesting and practically important question—Are these in their nature such as will suffice to account for the phenomena of transmissible disease?

Here let me observe that it is not my intention to give you an elaborate physiological disquisition upon the organs and functions of the human body, to distinguish and describe the

processes of nutrition or *in-taking*, and of excretion or *out-putting*. It is enough for our present purely practical ends to know that the life of a man consists in a condition of perpetual instability within the body, and as a necessary consequence without it, in the surrounding adjacent *media*. By the mouth we take in, and by the mouth, the bowels, bladder, and skin we give out. Taken in the mass, the matters given out by the mouth are primarily imparted to the surrounding atmosphere, those given out by the bowels and bladder to the soil and the water therein, those given out by the skin, in the first place to the clothes we wear or the coverings under which we lie, and also to the air. Those excreted matters may in a similar rough and familiar way be classified into water, air, certain definite products capable of isolation—some simple, some complex in their chemical constitution—and solid particles of our tissues retaining organized structure, suspended in the air and water, cast off from our skin, or mixed up in the masses of animal, vegetable, and mineral substances—the undigested remains of our food—which have never really been part and parcel of the body through which they have passed. The rapid progress of the express engine is marked not only by the production of steam and smoke and cinder, but by the scattering of a fine dust mingled of fragments of its own machinery and of the rails on which it runs. So it is with the machinery of our bodies. It leaves behind it not only vapour, and carbonic acid, and complex organic products, and the ashes of unconsumed fuel, but fragments of its own substance. If we take a garment which has been worn next our skin and shake it vigorously in the path of rays of sunlight, an immediate increase in the motes, or fine particles floating in the air, demonstrates to the naked eye the superficial debris of our bodies. If we

take a glass vessel, fill it with ice, and catch the drops of moisture condensed from the air of a crowded room, the microscope will disclose organic particles carried out from our mouths with the breath, and from our skin with the invisible vapour of perspiration. In the discharges from our bowels and bladder particles may in like manner be discovered, many of which can be readily recognized as peculiar to those parts of the internal organs and surfaces from which those discharges come.

Such being the method of our vital processes, you will at once admit that wide as the world is, it is a mere question of the degree of proximity of one human being to another, whether, and to what extent, there shall be a mutual interchange, not merely of the definitely constituted and analyzable products of those processes, but of actual, solid and substantial fragments of their bodies. It is impossible for me, in the short time at my command, to give you even the shortest summary of the evidence which has in recent years been accumulated by observation and experiment, and which points, in my opinion, with perfect certainty to this conclusion, that the infecting element in all specific and transmissible diseases is an organized solid, something having weight and dimensions. There is diversity of opinion as to whether those particles are independent existences, belonging to the lowest and most rudimentary forms of animal or vegetable life, or perhaps wavering in an intermediate state; or even whether they are not, at any rate in certain forms of disease, originally fragments of the animal body which have somehow or other acquired a poisonous property which in health they do not possess. But passing by all those undetermined and debateable questions, there remains the important practical conclusion, which for sanitary and pre-

ventive purposes we must seize upon and keep ever before our minds, that among the various excretions and exuviæ of our bodies, which retain a particulate organic constitution when they leave our bodies and pass into the surrounding *media*—earth, air, and water—which are the common property of our neighbours; and so long as these particles retain their constitution in these *media*, are to be found the dangerous infecting elements against which all the resources of nature and sanitary science must be directed, so as to compass their destruction, or at least their control and dispersion.

Although I do not think it expedient, for reasons already stated, even if it were possible, to enter upon the wide and intensely interesting subject of the nature of the *contagia* of the different infectious diseases, as their particulate

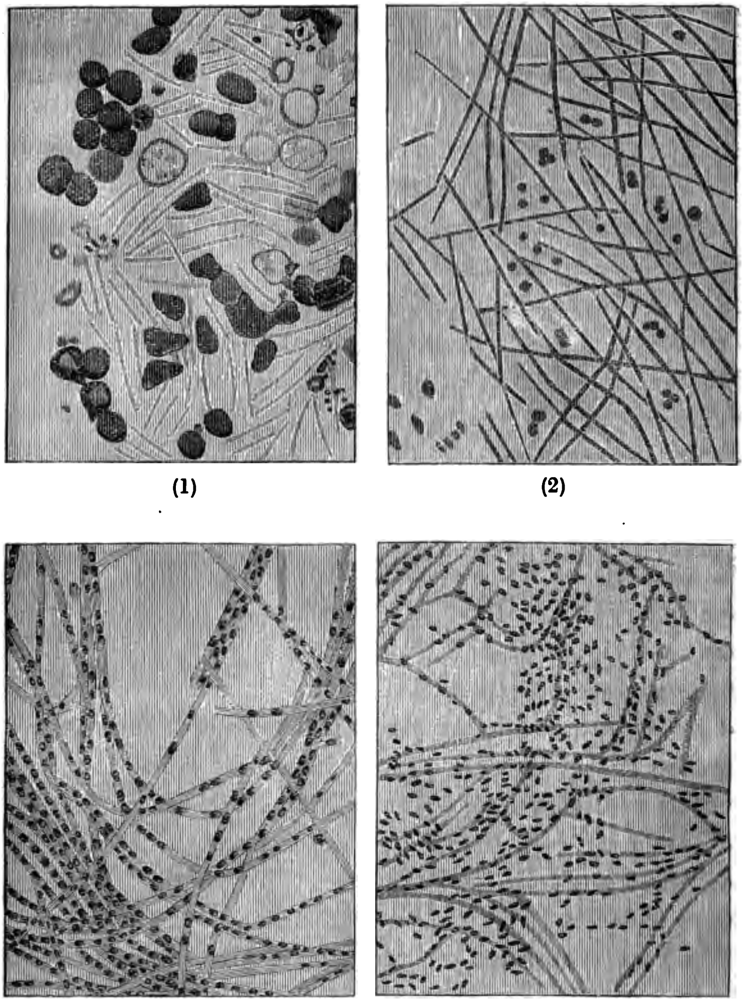
Fig. 1. Groups of Particles in fresh vaccine lymph, magnified 500 diams. (*Sanderson, Report by Medical Officer of Privy Council*, 1869, *p.* 232.)

infecting elements are called, I may in a few words stimulate your curiosity as well as give you some facts as a basis for your general belief. I am enabled through the kindness of my friend, Dr. Joseph Coats, Lecturer on Pathology at the Western Infirmary, to show you in those diagrams specimens of the particles to which I refer, as they appear under the microscope. As you are aware, vaccination is the communication by inocculation or direct insertion into

the blood, of a communicable disease. The infecting material is the lymph. To the eye it is a limpid fluid, but under the microscope it is seen that in this fluid granules are suspended.

In the virus of Small-pox, of Sheep-pox, and of Glanders or Farcy, a disease of horses, similar particles exist, that is to say alike in outward form, though so vastly different in their physiological effects. In all these cases experiments have been made by which part of the fluid was isolated or abstracted from the granules and found to be harmless, while the remainder containing the granules was found to be virulent.

In another diagram you have an example of a particulate organism, one of the lowest forms of the vegetable kingdom, which is called the *Bacillus Anthracis*, or the rod-like fungus of Anthrax, a dreadful disease which chiefly infests animals of the horse and ox species, but which readily invades human beings, and in fact all warm-blooded animals. These infecting particles are motionless, straight, minute rods which may be discovered in every part of the body, in the tissues as well as in the blood. They grow into fibres or filaments, and finally fructify, the life of the individual bacillus terminating with the production of a number of spores, which are the oval bodies shown in the diagram. This is the life of the fungus, and it is the disease in the animal whose flesh and blood are the *media* of its existence. Experiments of the most conclusive kind have proved that this bacillus really is the infecting element of Anthrax. Filter out from the blood those rods and spores, and you have a harmless fluid. Mingle the filtrate, containing those rods and spores, with pure water, and the water acquires the virulent properties of the original blood.



(1) (2) (3) (4)

Fig. 2.—(1) *Bacillus Anthracis* as seen in the Blood of mouse killed by Anthrax. The dark bodies are blood-corpuscles. (2) Same after 24 hours' growth at temperature of 64°—68° F. (3) Same with spores developed in filaments. (4) Same with spores thrown free by death of filaments. All after microscopic photographs, magnified 700 diams., by Koch.—(Cohn's *Beiträge zur Biologie der Pflanzen*, Bd. ii.)

In another diagram you have the *Spirilla* of relapsing fever, a minute cork-screw-like organism which is found in the blood in this fever, which you may remember prevailed so severely in Glasgow in 1870-71. This disease is active in

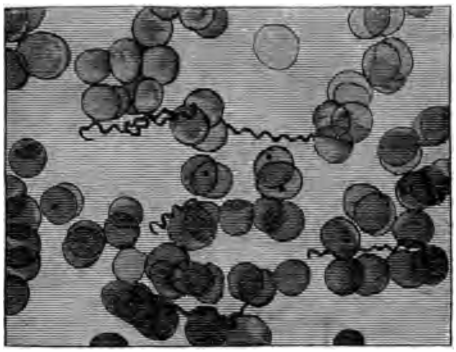


Fig. 3—*Spirochaete Obermeieri* in Blood of man, aged 22 years, 28 hours after beginning of first relapse of Relapsing Fever. The dark bodies are blood-corpuscles. After microscopic photograph by Koch, magnified 700 diams. (*Op. Cit.*)

the patient for a week, then it suddenly disappears for a week, and then as suddenly reappears. Hence the distinctive name. The spirilla is found when the fever begins, goes when it goes, returns with it, and finally disappears with it.

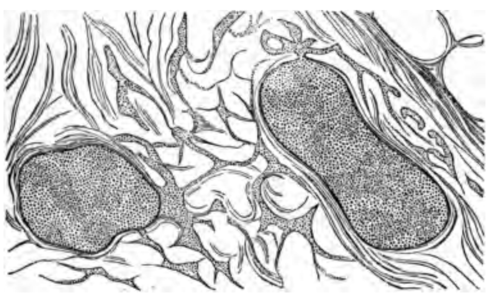


Fig.4—Section of deeper layers of Skin in Erysipelas, showing lymph spaces and lymph vessels full of Micrococci; magnified 650 diams. After Lukomsky, (Virchow's *Archiv*, Bd. lx.)

Dr. Coats has also given us a drawing of a section of the skin

in Erysipelas or "Rose," an infectious constitutional disease, accompanied by great redness and inflammatory swelling of the skin and subjacent tissues.

The dotted portions are lymph vessels and lymph spaces, and the dots represent myriads of micrococci, another form of fungus development. Similar minute organisms are observed in diphtheria, and in other communicable diseases; but as you will readily understand it is impossible by experiment in the case of diseases to which only man is susceptible, to do that which has undoubtedly been done with the *Bacillus Anthracis* and in other diseases of the lower animals—to prove that in those organisms we see the very infecting particles. Therefore some of them may be, not the cause of the disease, but merely an accompaniment. But, however this may be, what I say is this, that in all infectious diseases, the vehicle of infection is a solid particle of some sort, organized, however simply, and that in their entrance into and exit from our bodies, they depend upon the activity of our ordinary functions, and as we encounter them in nature they are associated with the components of the normal excretions. Therefore, the first line of our defence against their specific infecting invasion is to be sought in the laws of nature for the reduction and redistribution of those normal excretions into their original elements, and in the aggregate, those diseases find us open to, or more or less protected from their invasions, in proportion as we are living in harmony with, or flagrantly violating those laws.

What then are the natural forces which we can summon to our aid, and with which we may form a friendly alliance in this struggle with disease? What are the arrangements and laws of nature with which we must endeavour to co-operate,

and which, above all things, we must endeavour not to obstruct or to thwart?

"The animal," says Mr. Huxley,* "destroys living matter and the products of its activity, and gives back to the earth the elements of which such matter is composed, in the form of carbonic acid, ammoniacal and mineral salts. The plant, on the contrary, builds up living matter, and raises the lifeless into the world of life. There is a continual circulation of the matter of the surface of the globe from lifelessness to life, and from life back again to lifelessness." Our excretions are therefore dismissed from our bodies, not with a malignant, but with a benignant purpose. Even within our bodies they tend towards simplicity, and once outside our bodies, they are or ought to be immediately committed to the simplifying, reducing power of earth, air, and water. All we have to do is to give these simplifying activities facility for their operations, and the most obstinate of these complex products will ultimately be reduced to the simplicity and harmlessness of inorganic matter. The carbonic acid given off from our lungs is noxious, just as the carbonic acid evolved by soda-water, or from the decomposition of chalk in an acid, is noxious, neither more nor less. The nitrates and nitrites, the ammonia and phosphates, which indicate the previous sewage contamination of water, possess merely the properties of these salts as they are produced in the laboratory of the chemist. The sulphuretted hydrogen formed in our bowels, or from the matters evacuated through that channel, has the same physiological effects as the sulphuretted hydrogen manufactured in the chemical retort. And so with all the definite chemical products of the physiological laboratory which

* *Physiography*, p. 228.

can be separated by analysis. They have their well-ascertained properties. They are all even injurious to animal life if allowed to accumulate within the body, or if not prevented from returning directly thither. The fact that they are expelled from the animal economy is a sufficient indication of their having ceased to be useful, and even become obnoxious to health; but even though they produce disease it is not disease of a communicable sort. It may kill the unfortunate individual, but his disease and his death do not produce a risk to his neighbours. Even this limited power to harm is, along with the more subtile powers of the infecting organized particles, soon destroyed in the laboratory of nature.

The destructive processes to which those cast-off matters are subjected are all processes of oxidation, and are all directly or indirectly effected by atmospheric air. They partake therefore of the nature of combustion. You know that according to the proverb—Fire is a good servant, but a bad master. From our present point of view it is both a good servant and a good master. In the maintenance of life it serves us well, in the exercise of those very properties whereby it masters us so soon as we die, either in whole or in part. It passes into our lungs and feeds the fire of life, and it attacks our excretions, and if we give it free access to their substance, speedily consumes them. The decomposing activity both of soil and water depends upon the air which they contain. We are told by the Rivers Pollution Commission that "the oxidation of the organic matter in water is effected chiefly, if not exclusively, by the atmospheric oxygen dissolved in the water; such dissolved oxygen being well known to be, chemically, much more active than the gaseous oxygen of the air." (Domestic Water-supply, p. 137). It

must be explained, however, that although in equal volumes the oxygen in water may be chemically more active than the oxygen of the air; as we find it in operation around us, from the more frequent renewal, and the greater quantity thus brought into action, air is much the most destructive agent, and soil and water are destructive in proportion to the air which they contain. It has been conclusively proved by experiment that the cleansing power of soil depends on its porosity rather than its chemical composition; in other words, upon the proportion of air which it contains. Hence a wet soil possesses but feeble oxidizing power, and the first step towards the restoration of this power is to remove the water by drainage and allow it to be replaced with atmospheric air. The best illustration of the relative activity of air, earth, and water, as decomposing agents, as well as of the conditions most favourable to the speedy completion of the process by each of those agents, is afforded by their action upon dead bodies. The organism to be destroyed is visible, but these microscopic particles of organized matter which constitute the most dangerous portions of our excreta are destroyed in those *media* under exactly the same laws. A carcase laid in the open air upon a hill-side is swept by the free air, whose activities are also stimulated by the sun's rays, and the tissues which clothe the skeleton soon disappear. If laid in a shallow, running stream, or moored near the surface of a deep river, the same result follows; and if buried in a porous, dry soil, after a time nothing but the bones and the denser parts, such as hairs, nails, or claws, &c., can be discovered. Under all these conditions there is more or less rapid renewal of the active agent. But if we enclose the carcase in a box, or plunge it in stagnant water, or bury it in soil which is saturated with water; instead of a clean and harmless skeleton, we get a

repulsive mass of putridity and offensive complex organic gases which impregnate air, water, and soil.

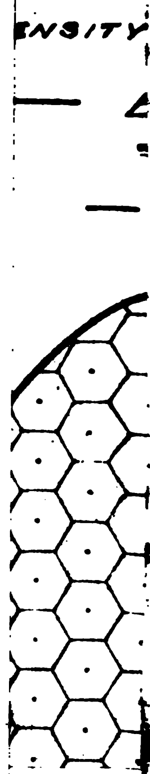
The physical properties of air in relation to soil and water, and to the gaseous and solid organic effluvia thrown off by the animal body, and in the final decomposition of organized matter, are wonderfully adapted to the efficient discharge of the great purifying function which I have described. I shall merely allude to them, leaving to the abler hands of my colleague, Dr. Wallace, their full exposition. There is, for example, the extreme solubility of air in water, the provisions in nature for the constant and copious admixture of air and water; and by the action of diffusion upon gases, and the rapid change of volume of which air is susceptible under the influence of temperature, for the dispersion both of gaseous and of suspended microscopic particles, whether decaying or protected by their vitality from putrefaction. But these properties of atmospheric air do not exhaust the special arrangements for the destruction of this suspended matter, and the maintenance of the lowest stratum of the atmosphere in which we live, in a state of purity. There is what Tennyson has beautifully named, "the useful trouble of the rain," which not only carries down with it dissolved gases, but washes the air of its suspended particles, conveying them into the earth, there to be eaten up by the roots of plants, or burned in the ground-air. Indeed the function of water as a carrier, or transporting and distributing agent, bringing organized debris within reach of vegetation and the more powerful action of the ground-air, is more important than its part as a direct purifier. We are chiefly indebted to German observers for our knowledge of this *ground-air* and its coadjutor *ground-water*. The ground-air is the air which occupies the porous upper surface of the soil, and the ground-

water is the water which fills up these pores beneath. The level of the ground-water in any locality is that at which the water in surface wells, which are not mere holes made artificially water-tight, will stand. All the soil above that is filled with the ground-air. As every one knows, the level of surface wells rises and falls with the seasons, and with a greater range according as the seasons are wet or dry. With this variation in the level of the ground-water which we *can* see, there is a corresponding variation in the depth of the ground-air which rests upon the water, and which we *cannot* see. In this way the earth breathes, and that, even to the extent of producing in its pores a veritable process of combustion of organic matter, and complex organic gases. The ground-water has not only a vertical but a lateral motion. It flows under the influence of gravitation, and guided by the degree of permeability of the different strata. The whole tendency of this circulation of fluid, which resembles the passage of the blood through the fine blood-vessels of the lungs, is to subject the dissolved gases and suspended particles to the disintegrating, decomposing action of ground-air. As the water subsides it leaves the solid particles entangled in the ærated meshes of the porous soil, there to be consumed; as the water rises it expels the partially deoxygenated air, to be replaced by fresh air when it again falls. At the same time, by the law of diffusion of gases, and the motion of the winds, a constant renewal of the ground-air is effected independent of this mechanical displacement.

In this description of the respiration of the soil, and the co-operation of air and water in removing offensive matter, and keeping the upper air and the soil clean, I have kept the idea of destruction in the fore-front. But economy of material is always uppermost in the arrangements of Nature.

Not only do those elaborate disorganizing processes produce gases and salts which are the food of plants, appropriated by root and leaf, but water transports within the reach of their spongioles particles of animal matter, and the, at first-sight startling, words of Dr. Alfred Carpenter are literally true—"An actual digestion of the animal matter takes place, without any reduction to organic salts" intervening.—(Preventive Medicine, p. 211.) Experiments have been made by Italian observers with coagulated albumen, and by a French observer with putrid meat suspended in water, in which the roots of growing plants were immersed, the result being that before their eyes the water was purified and its foulness transformed into healthy vegetable tissue.

I think you will agree with me, after this rapid survey, that the arrangements of nature for the prevention of diseases which may be caused by the infection of air, earth, and water, whether with the products of normal healthy life, or with those products when tainted with specific poisons, are theoretically perfect; but our rude illustration of a dead carcase enclosed in a box of stagnant air, plunged in a pool of stagnant water, or buried in earth saturated with water, must have brought home to your minds the fact that these arrangements are operative only under certain conditions. We have on the one hand an effect to be produced, and on the other a cause to produce this effect. There must therefore be some equivalence or proportion between the active agents and the work which they have to perform. In its widest, most abstract aspect, the self-cleansing powers of earth, air, and water, are purely physical. As such they come within the domain of measurement and numerical expression. We see this in the comparatively simple problems involved in ventilation; and although what we would require to do in



extending this exact method to the relation of the sum of all the functions of all the inhabitants of a town or district to the sum of the natural forces at work in air, earth, and water, within the area which they inhabit, is something utterly beyond the range of the practicable, it is conceivable as an actual relation. We can at least measure the superficial area of the earth, number the population which it carries, count up those who die, and note the diseases of which they die. We have here a sufficiently wide and stable basis of fact to work out the relation, and so get hold of the idea, that vast as are the resources of nature, they are not without limits; and that, as we add house to house, and man to man, in our cities, we had better have a care how we do it.

Look, now, at the diagrams headed "*Relation of Density of Population to Death-rate*" [see Plates I. and II.], in which I have endeavoured to bring your eyes to the aid of your minds in the comprehension of this somewhat abstruse doctrine. If you measure the area of an inhabited district—a county or a city—then ascertain the number of persons living within this area at any one time, and divide the population by the area, you get the proportion of the population to the area, and that we call the density of the district. We may express the density in various ways, *e.g.*, as the number of inhabitants per square mile, per acre, or per square yards, according as we measure the area in square miles, in acres, or in yards. We may also reverse the process and divide the area by the population, and so obtain the dimensions of the little area within which every man, woman, and child would stand if all were distributed equally over the district. If you imagine the population to be so situated, each person in the middle of their fraction of the earth's surface, we may obtain another and most interesting numerical expression of the relation of

man to man in a district, by measuring the mean distance from one person to another. This is called the *proximity*, or average nearness of one's neighbours—a mode of expressing density which brings to the front one of the most important elements, from our present point of view, in the complex circumstances involved in this compendious fact of density. The circles in these diagrams are, as you will observe, all of the same size, so that they enclose equal areas, and when I tell you that each black dot represents a human being, your eyes will at once convey to your minds a vivid conception of the very different relations in which the inhabitants of these areas stand to each other as to their number in proportion to the earth surface represented, as to the size of the little areas allotted to each, and as to the average nearness of their neighbours. The columns placed to the left of each circle exhibit proportionally to their height the degree of mortality prevailing within those areas, expressed as death-rates per million of the population per annum, on the average of ten years. You have then in these diagrams a graphic representation of the great law of human health, when taken in the mass, and tested over long spaces of time, that it is inversely as the density; that is to say, if you have two districts, such as two counties or two towns, of nearly equal superficial area, but differing in populousness, or the number of people inhabiting these areas, that county or town which is the most crowded will also be the most unhealthy—the amount of sickness will in the average of a series of years be the greatest, and the general death-rate the highest.

These diagrams will become more interesting and more convincing also, when you observe that they do not represent the state of matters in some town of Weissnichtwo, or in the country of Erewhon, but in certain well-known parts of the

United Kingdom. First look at the series of five. Dr. Farr, of the Register Office, Somerset House, London, to whom is due the credit of working out, by the patient labour of years, this important law of density, recently arranged the 593 Registration Districts into which England and Wales, exclusive of London, is divided, into seven groups, according to their density, on the average population of the ten years 1861-70. Taking the average death-rate of each group for the same period, he finds that just as the density increases so does the death-rate; from the most sparsely-peopled rural districts, with 166 persons to the square mile, and a yearly mortality of 17 per 1000 of the population, to the most closely peopled, with 65,823 persons per square mile, and a yearly mortality of no less than 39 per 1000 of the population. The diagram [Plate I.] represents only five of these groups, beginning with the thinly-peopled or rural districts, and ending with the dense area of Manchester Registration District. I have not added a circle to represent the circumstances of the population of Liverpool, because they so closely resemble those of Glasgow [see Plate II.], being somewhat worse, that the difference could not be shown on such a small scale. The following are the numerical facts regarding the density and death-rate in the groups of districts represented by those six circles, taking Glasgow, in Plate II., as the same as Liverpool:—

	Proximity in yards.	Acres per person.	Persons per square mile.	Death-rate per 1000.
I.	147	4·00	166	17
III.	97	1·70	379	22
IV.	46	0·372	1718	25
V.	28	0·142	4499	28
Manchester District,	17	0·051	12,357	38
Liverpool do.,	7	0·0097	65,823	39

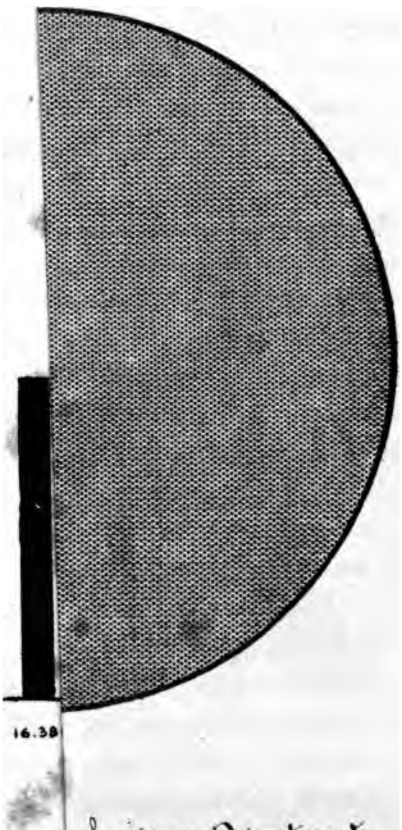
The other diagram [see Plate II.] brings us somewhat nearer home. The Scotch Registrar-General tells us that there are ten rural counties in Scotland inhabited at the rate of only 41 persons per square mile on the average of the ten years, 1866-75, while in Glasgow we endeavour to live in the proportion of 53,224 persons per square mile. The two circles show the circumstances of those populations in relation to the earth-surface. In the ten rural counties each man, woman, and child enjoys an ample area of 16 acres, and is 296 yards from each of his or her neighbours; while in Glasgow each citizen is "cribbed, cabined, and confined" within less than 1-80th of an acre, and is only 8 yards from his nearest neighbours. You will not be surprised to learn that in the rural counties only 17 per 1000 of these happy people die annually, while in Glasgow fully 30 perished in each of the years from 1866 to 1875. Shall we say that in Glasgow we choke and hustle each other out of existence? Do these facts admit of any other interpretation than this—that there are limits to the self-purifying powers of nature, that the laws of nature to which we trust for the purification of earth and air and water from the contamination of animal life, are effective under certain conditions with which aggregation interferes, and that a high death-rate is the penalty attached to our violation of these conditions?

Let us look into this law a little more narrowly. What does density mean in detail? To be still more precise, what does it mean in Glasgow? It means, to begin with, an area of 6033 acres (surrounded not by open or thinly populated country, but by dense populations), on which, or excluding parks, graveyards, and unbuilt ground, on some 4700 acres of which are aggregated 566,000 human beings, with thousands of horses, cows, and others of the lower animals. It means

Plate II.

RATE

SGOW.



Sanitary Department.
Glasgow. March 1879.

that three-fourths of those human beings live in houses of one and two apartments, that those houses are built in tall tenements, so arranged on the earth's surface as to exclude the sunlight and impede the circulation of the air; more especially that a large proportion of those tenements are arranged in hollow squares, which are boxes of stagnant air. It means that inside those boxes there are ashpits and privies, the superficial area of which, at a moderate computation, is 4½ acres; that planted among those ashpits we have hundreds of "back lands," along with stables, byres, bakehouses, workshops, washing-houses, and other smoke and effluvia-producing erections; that the stairs are often close and badly ventilated; that they are at best vertical streets, with lanes and alleys branching off at the several landings; that houses in flats planned for occupation by one family are occupied by several families, each renting one or two rooms, and the lobbies dark and tortuous by which they reach the stair. It means that a large proportion of the inhabitants are dirty in their persons, dirty in their clothing, bedding, and houses; that the atmosphere of their houses is foul, and the air in their lobbies and stairs is common to everybody living in the houses and using the stairs; that the courts and back-areas are full of impurities, animal and vegetable, and are only kept tolerably decent by the daily services of the public scavengers. It means that hundreds of factory chimneys and thousands of domestic vents maintain over all this devoted area a dense canopy of smoke, which in summer cuts off a large proportion of the sun's rays, an extra supply of whose decomposing energy ought if possible to be secured to aid in the destruction of the organic particles which are so rife in the air of cities, and which in the winter descends upon us with the watery vapour of our fogs. It means that the mass of our excretions is so enormous

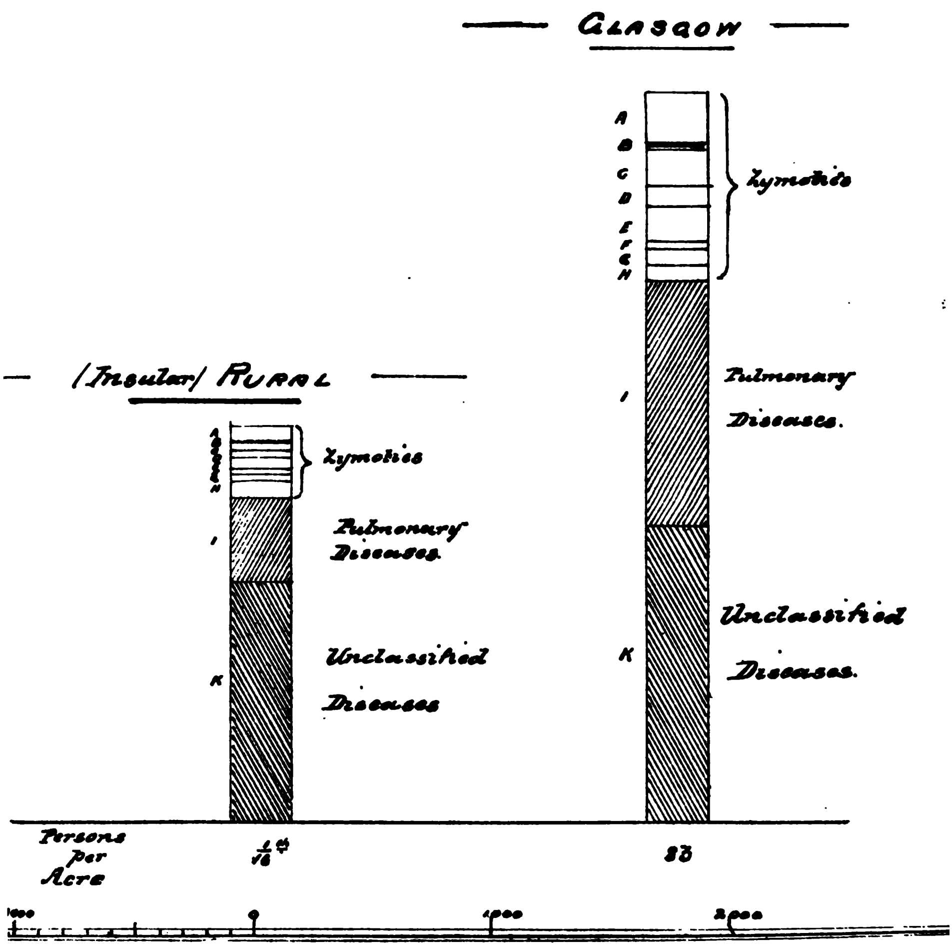
in relation to the earth and air-space, that to get them removed from our houses and their precincts water-carriage must be employed, and therefore our rivers and streams are loaded with the foulest refuse; that the subsoil is traversed by a net-work of sewers, drains, and gas-pipes, and is therefore so impure that the ground-air is loaded with noxious effluvia, and the ground-water is so foul that to drink it would be poisonous, if indeed it could be done. Finally, it means that for grassy fields we have stony streets, and in place of trees we have lamp-posts, and altogether we are as far shut out from the ministry of nature, as the necessities of the case, combined with the aggravations of human ignorance, perversity, and wilful self-aggrandisement, can place us.

You must often have heard your physicians speak of the type of the disease and the constitution, or as it is sometimes called, the diathesis of the patient. These terms refer to the different aspects presented by the same disease in different persons or in different families; or the tendencies towards certain classes of disease which are observed in certain individuals, or descendants from the same stock. The same or similar phrases have been used regarding countries and communities, and their prevalent diseases at different epochs. The words "epidemic constitution" have been so used to express an imaginary something in the earth, or in the air, in the sun, moon, and stars, in the universal cosmos—pandemic waves, chromospheric phenomena, magnetic disturbances, and various other mysterious transcendental conditions—which produced a special proclivity to epidemic outbreaks, or intensified their malignity. Be it observed, this is a most hopeless direction in which to direct the thoughts of mankind—quite as inaccessible to our direct

Density of Population and Composition of

Death-Rate

1861-1870.



Scale of Persons Plates II^{a} & III

influence as Apollo to the Greeks, when he twanged his silver bow, and men and horses fell beneath the arrowy plague. But I believe that in the conditions expressed in these diagrams of Manchester, Liverpool, and Glasgow, as interpreted in those details of the physical circumstances of our own city, *we have the true "epidemic constitution;"* and therefore we have complete control over it. Our own hands have made it, and only our own hands can unmake it. These lofty ideas of the nature of epidemics are reminiscences, lingering in traditions of the bewildered thoughts of our forefathers, concerning the terrible plagues of the past; but it is a matter of history that the habits of the people, and material circumstances of the houses and cities of those times were, as compared with the conditions of the present day, as much worse as the plagues of the past were worse than those of the present day. Just as the prevailing uncleanness was more gross and universal, so the mediæval epidemics were more frequent and more malignant.

In conclusion, let me ask your attention to the two columns in the coloured diagram headed "*Density and Composition of the Death-rate*" [see Plate II.[a]]. The short column shows the composition of a death-rate of 17 per 1000, and the tall column the composition of a death-rate of 30 per 1000, the former being the death-rate of certain rural districts of Scotland, the latter of Glasgow, the period on the average of which the death-rates were calculated being in both cases the 10 years 1861-1870. In order to bring the subdivisions of those figures, which are represented by colours, each colour showing what was the death-rate from a different disease or class of diseases, up to an amount distinguishable to your eyes, the rate has been taken per million of the population in place of per 1000, so that the respective death-rates become 16,388

and 30,292 per million in place of 17 and 30 per 1000. The scale chosen is one inch to 500 deaths, so that every inch in the height of each of these columns represents 500 deaths per million, or ·5 per 1000, and proportionately for each fraction of an inch.*

With these explanations, and without at present troubling you with figures, I would ask you to observe in each case the top of the column, which is formed of different strata, but is all bracketed off, and marked *Zymotics*. Below that in each column is a long stretch of a brick-dust colour, which shows the death-rate from diseases of the lungs, including Phthisis or consumption, and the base of each column is shaded with black, indicating all the remaining diseases, whose prevalence has no decided sanitary meaning, and to distinguish which would have been confusing and not instructive. Now look at these columns and contrast them. You are of course first of all impressed with the very great mortality in the city, as compared with the country, but you will also observe that the diseases which kill us in the city are different in kind

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* This was the scale of the large coloured diagram. That of the shaded columns in Plate II.[a] is shown at the foot of the plate. The following are the figures represented in the subdivisions of those columns, being the actual death-rates from each cause per million inhabitants in the Insular Districts of Scotland and in Glasgow, in the ten years 1861-70, taken from the Detailed Census Report, Vol. II. :—

	(Insular) Rural.	Glasgow.
A—Fevers, . .	627	2024
B—Small-pox, .	48	232
C—Scarlet Fever, .	210	1317
D—Measles, .	276	795
E—Hooping-cough, .	457	1507
F—Diphtheria, .	217	254
G—Diarrhœa, .	244	813
H—Other Zymotics, .	807	794
I—Pulmonary Diseases,	3542	10,240
K—Other Diseases .	9960	12,316
Total, . .	16,388	30,292

from those which prevail in the country. In the first place the mass of undistinguished and sanitary meaningless disease is very much alike in both circumstances. Indeed, the proportion of the total length of the column which is coloured black is less in the city than in the country. But how enormous is the death-rate from diseases of the lungs in the dense city as compared with the open country; and how great the ravages of Zymotic or infectious disease. Your eye will tell you that they each destroy three times as many lives in the city as in the country, and not only so, but they make a much larger contribution in proportion to the total height of the fatal column in the town than in the country.

Are these facts of the predominance of infectious and pulmonary disease isolated and independent in their origin. In designing those diagrams I had no thought save that of convenience in placing the Zymotic diseases at the top of those columns, resting upon the Pulmonary diseases, but as it turns out, the position is emblematic of their relation according to my theory of infectious disease. The circumstances of overcrowding of houses on the soil, and of people in the houses, of dirty persons, and the contact of those persons in badly ventilated lobbies, and crowded courts, in short, all those details of overcrowding into which I formerly entered are unceasingly operative producing ill-health, and they affect the organs most, which are most exposed to the impurity of the air, viz., the lungs. But ever and anon as the material infecting element is cast into the community, the epidemic constitution is developed. It is not created when the outbreak takes place, merely disclosed, merely demonstrated as by a fiery finger. Travelling along the paths of communication proved by the general ill-health to be constantly open, this

infecting element keeps up a constant simmer, so to speak, of infectious diseases, each propagated after its own kind, in its own special direction, and breaks out intermittingly under favourable conditions still of the same kind, into spurts and wide-spread overflows.

LECTURE II.

THE BREEDING-PLACES, THE CARRIERS OF INFECTIOUS DISEASES, AND THE CONTROLLING CIRCUMSTANCES OF INFECTION.

(December 3rd, 1878. Bailie Farquhar in the Chair.)

LADIES AND GENTLEMEN,

The Infectious Diseases of a country may be classified like its plants and animals. Some are characteristic. They are indigenous, or home-grown, always present and confined within their native limits by various conditions of climate, soil, habits of the people, &c.; others are of foreign origin, but have become acclimatised; while others again are only casual visitants, imported by extraordinary circumstances, but incapable of accommodating themselves to the novel conditions of existence. Another class of infectious diseases is cosmopolitan. They attach themselves to certain conditions of human life which may arise wherever man can exist. Having regard to our own country, typhus is an example of a native infectious disease; cholera of one which is of foreign origin, but capable of being acclimatised; yellow fever of one which has casually visited our shores, but cannot take roôt in an uncongenial soil; while small-pox is cosmopolitan.

Some animals and plants are propagated by a curious mode

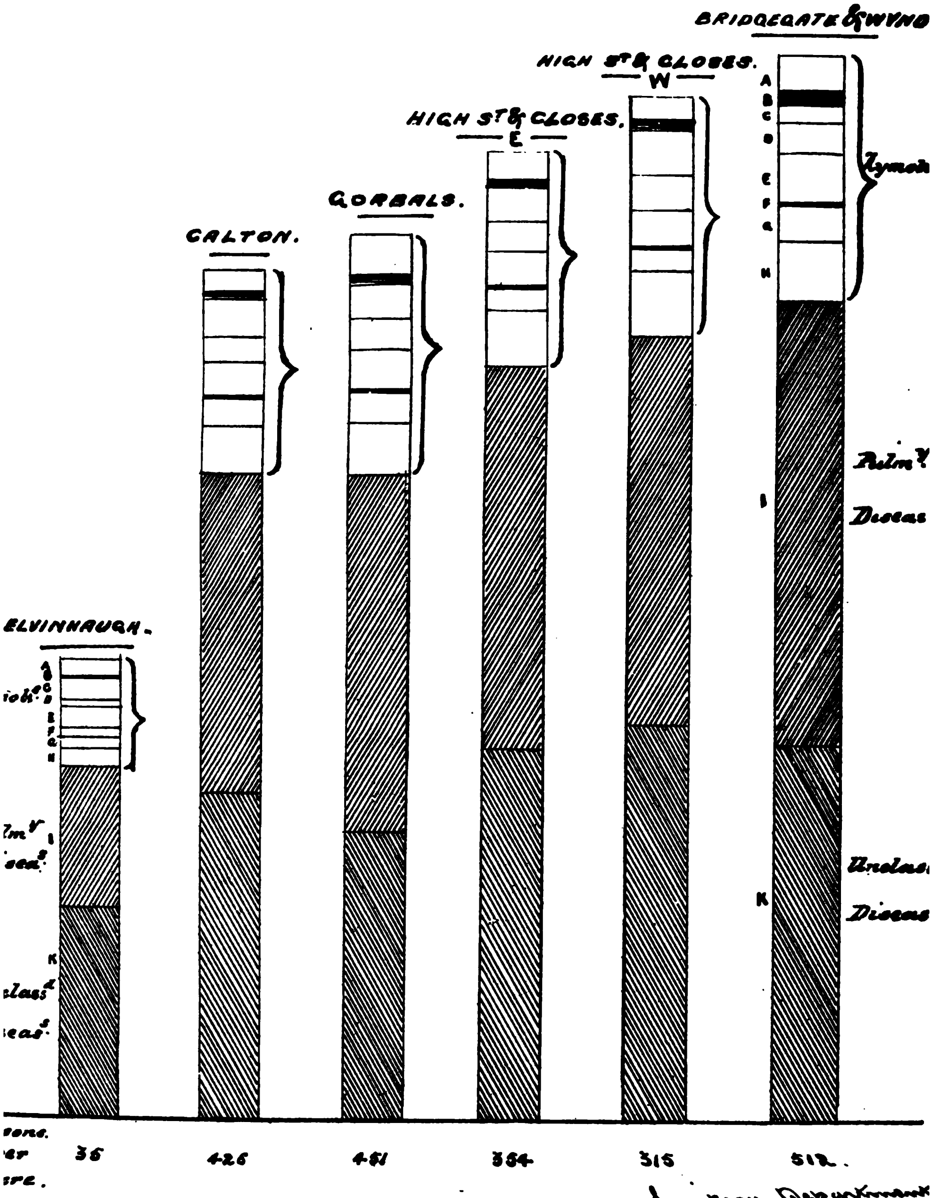
of self-fertilization, instead of by the more common arrangement by which two elements are produced in different individuals. If we regard the inhabited globe as an individual entity, then I believe that within historic times, in respect of infectious diseases, it has been truly self-fertilizing. We have no need to suppose that any local development of these diseases required a spontaneous generation of the infecting particles. At any one time, we may be sure, sufficient information would prove that no specific disease is everywhere extinct. In throwing out this idea I am, however, entering upon the region of speculation. Confining myself to the sphere of experience, I can safely assert, in reference to Glasgow, that none of our indigenous epidemic diseases ever are totally extinct, and none of our casual visitants, even though they may not have been seen for years among us, ever have disappeared from their habitats in other countries. In respect of typhus, enteric fever, scarlet fever, measles, hooping-cough, and diphtheria, Glasgow is certainly self-fertilizing. Or to change the metaphor to one which you may perhaps understand better—we grow our own weeds. Sometimes, no doubt, we are indebted to our neighbour's garden for a few, but they are quite unnecessary to maintain the stock. I now propose to show you where, in the body of this community, infectious diseases have their *breeding-places*. For this purpose you will please direct your attention to the large diagram entitled—"*Breeding-places of Infectious Disease in Glasgow*" [see Plate III.]. The columns in that diagram each represent the composition of a local death-rate within the municipal boundary. They are drawn upon the same scale adopted in the other diagram brought under your notice in my first Lecture, where the composition of the death-rate of Glasgow as a whole is contrasted with that of the insular-rural districts

Plate III

— BREEDING PLACES OF INFECTIOUS DISEASES —

— GLASGOW. —

— Death Rate per Million. — Years 1871 - 1875. —



— Sanitary Department
— Glasgow March 18

of Scotland. One inch in the height of the columns represents 500 deaths per million of the population yielding the death-rate—a million being chosen as the basis of calculation instead of the more usual thousand, merely to bring the figures within appreciable dimensions.* Taken as a whole, each column represents the average death-rate of a district of Glasgow for the five years 1871-75. The short column to the left stands for the healthiest district, that of Kelvinhaugh and Sandyford, with a density of 35 per acre, and a death-rate of 19 per 1000. The five tall columns, each in succession rising higher, bear the names of certain well-known parts of the city. There is Calton, with a density of 426 per acre, and a death-rate of 35½; then Gorbals, with a density of 450 per acre, and a death-rate of 38; High Street and Closes (E.), with a density of 354 per acre, and a death-rate of 41; High Street and Closes (W.), with a density of 315 per acre, and a death-rate of 43; and last of all and tallest of all Bridgegate and Wynds, with a density of 512, and a death-rate of 45.

Now, without further reference to figures, cast your eyes along those columns in the diagram of last Lecture [see Plate II.], contrasting Glasgow with insular-rural Scotland, and then in the diagram of this evening, contrasting Glasgow with itself, and what do you observe? In the first place, as to the general death-rate, that the contrast is greater between the healthy and the unhealthy parts of Glasgow than between Glasgow as a whole and the open country; or to put it in another way, you have, even within the municipality of this city, 23,000 people whose mean annual death-rate for five years was only two

* The Scale of Plate III. is the same as that of Plate II.

above that of a rural population. Yet a few hundred yards from these very people you find 80,000, whose mean annual death-rate during the passage of those same years ranged from 35 to 45 per 1000. Now, whatever may underlie this fact, it proves this—that it is not the situation, the soil, the climate, or any other physical circumstance common to the whole area, which produces our high death-rate. In short, whatever the cause or causes may be, whether they be physical or moral or an admixture of both, they are not necessary; and therefore our condition is not absolutely hopeless, but eminently hopeful. But I go further than this and assert that the moral contrast between those two classes of our population is not so violent as that between their physical circumstances; and I ask each one of you to look within and consider the mysterious action and re-action of body and soul, of flesh and spirit, of which every man and woman is conscious, and say who will throw the first stone at these poor people in respect of their moral failings in view of their physical condition and surroundings?

If you look further, to the composition of the death-rates represented in those columns, you will observe also that the diseases which kill the inhabitants of the rural districts, and those which kill the inhabitants of the healthiest district of Glasgow are very much alike. They contribute much the same proportion to the total death-rate. There certainly is a decided excess of fatality from diseases of the lungs, and from infectious diseases, even in the healthiest parts of the city, but only enough to show that they form part of the same community, and are affected by the disadvantageous circumstances of the poor and unhealthy quarters. How eloquent as to the gravity of those circumstances are the component parts of those lofty columns! How enormous is the fatality

from diseases of the organs of respiration, which exhibits the constant and deadly influence of overcrowding, and all those details of contamination into which I entered so fully in my first lecture; and there too you have the Breeding-places of Infectious Disease. Their sufferings from bronchitis or consumption may not affect us much, except through our poor-rates; but their typhus, and small-pox, and scarlet fever, invade our homes and compel interest if not sympathy, even from the most selfish. In the course of my official duties I am often reminded of Dr. Alison's story of the poor Irish widow in Edinburgh, whose husband had died of typhus, and who, herself ill, wandered about seeking help but finding none, until at last she sank down and died, and in the locality where she died set the fever agoing; and ultimately seventeen other persons were carried off by her disease. The story is embalmed in one of Carlyle's works. Its grim sarcasm strikes him and he says, "Very curious. The forlorn Irish widow applies to her fellow-creatures, as if saying—'Behold I am sinking, bare of help: ye must help me! I am your sister, bone of your bone; one God made us: ye must help me!' They answer, 'No, impossible; thou art no sister of ours.' But she proves her sisterhood; her typhus fever kills *them*: they actually were her brothers, though denying it! Had human creature ever to go lower for a proof?"—(*Past and Present*, Book iii., Chap. ii.)

Although I have chosen the districts whose names stand at the head of those columns, and called *them* specially "Breeding-places of Infectious Disease in Glasgow," they are merely types of the kind of localities which are the home and haunt whence these diseases sally out upon the community. There are many such in this city, and I have selected those, because they are the very places which your Improvement

Act was designed to clear out and reconstruct, that you may know how to value the wisdom as well as the philanthropy of the citizens who conceived and obtained the provisions of that Act. Yet you remember what reward was meted out to the late Mr. John Blackie, jun., who was the leader of those far-seeing men, when the first imposition of the Improvement Tax touched the pockets of the community! From the narrowest and most selfish point of view, never was the public money applied more directly to further the immediate interests of the inhabitants of Glasgow; and you have fresh work of the same profitable kind awaiting you in many other parts of the city. The facts I have now put before you are embodied in the preamble of the Artizans' Dwellings Act, which appeals truthfully to our selfishness when it asserts that "fevers and disease are constantly generated there, causing death and loss of health, *not only in these courts and alleys, but also in other parts* of such cities and burghs."

Let us now examine the natural history of these infecting particles, or *contagia,* as they are called. They are organized structures, living entities, and, like all living things, they are endowed with properties designed for their propagation and continuance. It is, indeed, the exercise of these properties—the endeavour to multiply and propagate their kind, which constitutes the disease; *therefore every infected person becomes a breeding-place.* The tissues and fluids are consumed and contaminated. Even in the realm of visible plants and animals, whose seeds or eggs are not too small to be counted, we find examples of the production of those rudimentary particles in enormous numbers. Mr. Buckland counted 6,867,840 eggs in a single codfish. We are told that an Ascaris, an intestinal worm which infests man and

other animals, produces about 64 million eggs; and in the vegetable kingdom, that one Acropera plant would yield in a season above 74 millions of seed. These enormous sums give but an inadequate idea of the quantity of infecting spores produced within the body of a single animal, in which the *Bacillus Anthracis*, whose mode of propagation is depicted in the diagram on the wall [see Fig. 2, p. 14], has established the disease called Anthrax. The Cattle-plague Commissioners tell us that when a minute portion of the mucous discharge from the nose of an animal affected with rinderpest is introduced into the blood of a healthy ox, the accompanying contagium increases so fast that "the whole mass of blood, weighing many pounds, is infected, and every small particle of that blood contains enough poison to give, within less than 48 hours, the disease to another animal." So it is with small-pox, scarlet fever, measles, hooping-cough, typhus fever, enteric fever, and all other communicable diseases. Nor in some of this class of diseases is this effort at continuance and propagation confined to the body of the patient. All these contagia have the power of living outside the body in their appropriate media for a longer or shorter period, and at least those of cholera and enteric fever may even propagate in those external media. In this way the discharges of those diseases, when mingled with healthy excretions, act like a leaven, and confer their specific infecting power upon the entire mass. I have a very strong suspicion that the enteric or typhoid contagium multiplies in milk, a vital fluid which provides nutrition for it almost as appropriate as that of the blood. It is scarcely possible in any other way to account for the virulent infecting power of milk contaminated with what in many cases must be an infinitesimal quantity of the original virus.

Another feature of all infectious diseases, which has an important relation to their propagation, is this, that when once established in the individual, they not merely confer an infecting power upon one or more of the normal excretions, those excretions continuing otherwise in bulk and physical properties unchanged. There is from the very outset a stimulation and increase of the processes of life; and consequently an increase in the quantity as well as a change in the quality of the debris thrown off by the usual channels. I need only recall to your minds the febrile condition, the hot skin, the throbbing pulse, and the general appearance suggestive of the vital machinery flying round under some unusual stimulus. Accompanying this you have, according to the disease, singly or more usually combined in groups—diarrhœa, perspiration, sneezing with running from the nose, coughing and expectoration, slight casting of the skin, producing bran-like dust, or free and rapid, producing large scales and flakes; or suppuration of the skin, producing scabs and crusts. In cholera, diarrhœa, vomitting and perspiration go on without ceasing, until the unfortunate patient is left shrivelled and externally cold like the dried husk of his former self. Each disease has one or more favourite channels by which its special contagium is eliminated or "turned out of doors"; but we do not know enough of the subject to warrant us in saying that any excretion of an infected person is free from infecting particles. If then you add all these facts together—the enormous propagation of those particles within the body, their constant struggle to leave the body, the increased amount of the excretions which contain them, and the duration of the disease, ranging from a few hours in cholera, to several weeks in enteric fever and hooping-cough, you can be at no loss to understand what ample material for

the spread of the disease a single case provides. Numerical calculations and estimates are of no value, save as a slight help to your minds in rising to some notion of the quantity of this material; and solely for this purpose I may mention that Dr. Farr, who delights to bring everything under subjection to his mathematical faculty, estimates that in cholera, if the fluid discharged from the bowels alone, contained infecting particles in the same proportion as the microscopic particles called blood-corpuscles exist in healthy blood, there would be 42,000 millions set adrift in the surrounding media during the progress of an average case.

We come now to the Carriers or distributors of infectious diseases. The works of Darwin are full of illustrations of the careful and almost infinitely various provisions for the conveyance of the fertilizing elements, and of the seeds, especially of plants—what he calls the "means of dispersal." They are transported by air and water, either alone or adherent to larger bodies, alive or dead; they are eaten by birds, fishes, or insects, and spread far and wide in their excrement; they adhere to the fur or hair, and are mixed with the earth on the feet of animals. In the distribution of the *contagia* we may observe similar agencies at work. Happily for mankind, owing to the operation of a controlling law of infection which I shall explain shortly, effective conveyance of these particles is rarely accomplished by the *open* air. Air must be more or less stagnant or confined, or the poison unusually dense, to make it infectious. Yet such a circumstance as the violent effervescence of sewage containing the excreta of cholera patients may spread cholera in the neighbourhood, as happened in Southampton in 1866, and in the neighbourhood of the Thames in 1849. Quite recently Dr. Frankland, by ingenious experiments, has shown that bubbles rising through

a liquid and then bursting at the surface, project violently into the air any particles adhering to the film which encloses their gaseous contents. This diagram will show you the

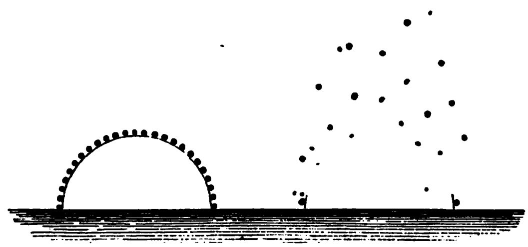


Fig. 5.

physical circumstances of this mode of dispersion. If air be confined, as it is in crowded apartments and ill-ventilated lobbies or staircases, it then is a potent carrier of infection. Pettenkofer, a German chemist and hygienist of great ability, regards the ground-air as a very frequent, if not in some localities the chief, mode of conveyance of the contagia of enteric fever and cholera. There is, at any rate, sufficient substance in his facts to warn us to be very careful to avoid cellar dwellings, and in general to cut off the basements of our houses from free communication with the subsoil, by the use of asphalt or some other impervious covering beneath our floors. The other universal medium common to communities, viz., water, is undoubtedly capable of acting as a carrier of infection in its most potent form. The most violent and wide-spread epidemics of cholera and enteric fever on record are almost, without exception, the result of the contamination of the water-supply. Another public distributor of infectious disease is the artificial production of the sanitary arrangements of towns. I refer to our sewers, with their infinite subsidiary ramifications in drains and soil-pipes, and I

call them nevertheless *sanitary* arrangements, because their attendant production and dissemination of sewer-gases are examples of subordinate defects which we see mixed up with great and predominant advantages in all human devices. They have not created any new diseases, and being most frequently the infecting medium associated with certain diseases (which are in truth essentially connected, not with sewers, but with one portion of our excretions, as such and however treated), in towns, where most of our intelligent sanitary investigations are made, they have come to be spoken of as if they were the chief, or even the only, universal infecting medium of those diseases. Wherever men are, you have these excretions, and wherever you have these excretions you have a possible source of infection, the extent to which this infection becomes operative in the community depending upon the fitness of the method of disposal adopted to the physical circumstances of the locality, and the amount of common-sense and practical care and intelligence brought to bear upon the details of the method. With these remarks I leave these carriers of infectious disease, which would afford ample material in all their aspects for a separate course of Lectures.

But I have not done with the carriers of infection. Nothing which I have yet said can have brought home to your minds with sufficient vividness, the dangers arising from the existence in a large city of those breeding-places of disease which are represented in those diagrams. Look at the five broad bands or stripes of colour which stand at the upper ends of those columns, exhibiting to your eyes the chronic epidemic prevalence of the five diseases, Fever (mostly Typhus), Small-pox, Scarlet Fever, Measles, and Hooping-cough, in the Bridge-gate, High Street, Gorbals, and Calton; remember that, as I have already told you, those districts are merely samples of a

state of things which exists in a somewhat less degree, in many other districts of Glasgow, and then endeavour to comprehend what that means for every citizen within the municipality, no matter where he lives, no matter how attentive he may be to the sanitary arrangements of his house, no matter what precautions he may adopt to shut out those infectious diseases from his household. Look at those black dots studded over the circular area in the other diagram, and representing the proportional distribution of the inhabitants of Glasgow, and the average relation of one person to another, supposing all equally spread out over the surface, and each stationary in this average position in reference to his fellow-citizens [see Plate II.]. Even on this supposition what chance would a man on the outskirts of that area have of escaping, if in the centre any one of those diseases were once set a-going? Then, in place of this unreal and purely imaginary condition of equidistance and fixture to one spot, consider what is the actual condition of constant intercourse of man with man, constant contact of high and low, rich and poor, clean and dirty, well-housed and well-fed with badly-housed and ill-fed, healthy with diseased, in this vast hive of humanity. The result is patent to your eyes in the existence of those smaller bands of the same colours in the West-end district of Kelvinhaugh and Sandyford. If by any magic wand we could abolish those central districts, or rather the conditions of overcrowding, dirt and thoughtless ignorance and carelessness which prevail, then those diseases in their epidemic aggravations would disappear as surely as the shadow follows the substance; unless indeed, our friends in the country continued to send us a fresh supply along with their other articles of produce. Perhaps you may think that I indulge in the pardonable exaggerations of an enthusiast, but I speak with a knowledge of the facts of

infection derived from close observation, which it is almost impossible for me to put into your minds. Take a single overcrowded house. Enter it. The air is so loaded with animal impurities that you gasp for a satisfying breath, and when you leave, your clothing smells foully with the effluvia retained in its meshes. Such a house, in a populous locality, is like a barrel of gunpowder. Cast into it the sparks of any one of those diseases, and an explosion will follow which will involve not only the inmates of that house, but the whole neighbourhood, in ruin and desolation. Their wearing apparel, especially if they follow the common practice of sleeping in the clothes they wear, their bedding, if they have any, become saturated with the poison, and wherever they may go, and to any one who approaches them they are a source of danger. The most ordinary incidents of life, the every-day occurrences of employment, their use of public conveyances, their friendly visits, their family relationships, their courtships, their marriages, their congratulations over their births, and their funeral ceremonies and condolences, are at once raised into acts of public interest, and dire significance. Their children go to school, and spread *their* special diseases. They pawn their clothing and bedding, and the pawnbrokers are attacked. They sell them, and families miles away are infected. But, some one may say,—still these facts do not touch me, living in the Crescent or the Square. Where do your "hewers of wood and drawers of water" live? In such places as those. You have message-boys and girls bringing home your goods; you have dirty children employed in the distribution of milk; your letters and telegrams, and newspapers are delivered by men and boys who may come from such localities. Your domestic servants have friends and relatives there. Your casual assistants in household work, your char-

women and washerwomen, live there. The clothes you wear may be made there, and I have seen them used to eke out the scanty bed-clothing of sick people in such houses. Perhaps your washing and dressing is done out of doors, and who can tell where the laundrywomen and washers may live. In making a tour round some of the fever-haunts of London some years ago, I was greatly astonished on following my guide into an alley in Whitechapel, to find it radiant with cut flowers, which hid even the gutters, and were strewn on the steps of the houses, and in the houses themselves. The place was inhabited by those flower-sellers who frequent the thoroughfares of London. There they were, chiefly women, busy sorting their treasures into tempting bouquets, made up with the help of their squalid children in a Whitechapel alley, and sold to ladies and gentlemen in Regent Street. These are only a few facts, suggestive of many others, sufficient I hope to raise your notion of the intimate relationship existing between the extremes of the social scale in a large city, from a vague impression into vivid reality. Infectious diseases take advantage of these relationships, as they do of all others, exactly under their every-day conditions. They do not create them, but they may demonstrate them with grim and terrible distinctness. And you are not to suppose that gross overcrowding and dirt alone will make human beings carriers of the *contagia*. The M'Larty family has a very extensive, and be it said a very respectable "connection," extending to all degrees of relationship. There are the untidy, and the slovenly, as well as the abominably dirty, and according to their degree, all are apt and constant carriers. Even without these avoidable aggravations, the mere element of proximity is enough to make the conveyance of infection inevitable. I have told you that three-

fourths of the inhabitants of Glasgow live in houses of one and two apartments. Let those of you who live in large self-contained houses bethink yourselves of the precautions which you adopt under the directions of your physicians, when any of your children take scarlet fever or measles, to prevent the infection of the others; how often indeed you remove the healthy children from the house, and yet how often all your precautions fail of success; and you may more clearly see that the most scrupulous cleanliness, and the most intelligent special arrangements must be quite inadequate to overcome the tendency of such diseases to spread in small houses in flatted tenements.

The observation of such circumstances as those was the first step towards a rational theory of the propagation of epidemic diseases made in ancient times, and hence the term "Contagion," which strictly speaking, includes only propagation by personal contact. You will remember the vivid description given by various authors, of the feverish terror which the perception of this danger begot in the popular mind during times of pestilence. Defoe's History of the Plague in London derives much of its tragic interest from its graphic illustrations of the disruption of social intercourse, under the influence of this alarm; but the author of "Eothen" has given us the most realistic and picturesque description of the mental agony of the man who is pursued with the idea, that the pestilence walketh at noonday. He says: "to the contagionist, . . . one, every rag that shivers in the breeze of a Plague-stricken city has a sort of sublimity. If by any terrible ordinance he is forced to venture forth, he sees Death dangling from every sleeve, and as he creeps forward, he poises his shuddering limbs between the imminent jacket that is stabbing at his right elbow, and the murderous

pelisse that threatens to mow him clean down, as it sweeps along on his left. But most of all he dreads . . . the touch of a woman's dress, for mothers and wives hurrying forth on kindly errands from the bedside of the dying, go slouching along through the streets, more wilfully and less courteously than the men." Mr. Kinglake speaks of Cairo during the prevalence of the Plague, but making allowance for some measure of poetic license, he describes the real risks to which the general public are exposed, when the much less virulent plagues of our Western cities are intensified in contagious power, by the personal uncleanness of too many of our poorer fellow-citizens. I must also say that, as in the East so here, from the bulk and many folds of their garments, the women are most to be feared. We have only to keep our eyes open, and our noses alert to the condition of many of the passengers by the tram-cars, to become aware that they are travelling magazines of infection. For poverty we ought to have all sympathy, but to dirt we ought to show no mercy, and such persons ought to be excluded from all public conveyances.

Having now discussed the Breeding-places of Infectious Disease, and obtained some conception of the enormous development and new creation of the Contagia or infecting particles in those breeding-places, we now proceed to consider certain laws which control and direct the *fact* of infection. Throughout the entire realm of living creatures we find that the elements or rudimentary particles by means of which the beginnings or foundations of new life are made, and the great design of continuance and propagation carried out, are produced in excess of the absolute requirements of this design. At anyrate nature is never niggardly of those fertilizing or germinating particles, and can always allow them to be freely

diverted to other useful purposes, without defeating or impairing the main design. Confining our illustrations to the vegetable world, I need only remind you how the fertilizing grains of pollen are scattered broadcast upon the winds in the case of many plants, upon the waters in the case of others, and entrusted to the busy legs of bees and other insects, in the case of many more. It is quite certain that a very small proportion of the total number of grains produced is applied to the prime purpose of fertilizing those plants. It has been found by actual counting and observation, that in the case of one species 81 times more pollen grains are thrown off than are required for the mere continuance of that species, so that after fertilizing its seeds with one part, there are 80 other parts left to be eaten by insects, washed away by the rain or otherwise disposed of. So it is with the matured seeds. What a bountiful supply of food they provide for man and other creatures, as well as for the continuance of their kind. The Parable of the Sower affords an excellent as well as a familiar illustration of the various fate of seeds of all kinds. We cannot follow out the ultimate distribution of the infecting particles or contagia quite so clearly, but it is certain, in the first place, that a very small proportion of their enormous number goes to the propagation of disease; and, in the next place, it is highly probable that a large proportion is diverted to what we may call more benignant ends, to the feeding of animals and plants.

Another most interesting and important general law has been made out concerning one class of those rudimentary particles which are employed in the maintenance of life, or rather concerning the small portion of this special class of particles which is ultimately economized in that way, and it is this—that a certain quantity is necessary to fertilize. I

have said that this *law of quantity* applies only to one class of particles; that is, again confining ourselves to the vegetable world for our illustration, to the pollen grains but not to the seeds properly so called. One seed will always produce a perfect plant, if that seed has been fully fertilized; but for proper, effective fertilization, several pollen grains are necessary. You will scarcely be prepared to hear that these are not vague guesses from general averages, much less random statements, but are founded on precise experiments made by German and French botanists, whose observations you will find quoted in that great storehouse of exact facts regarding life and its beginnings --the works of Darwin (Animals and Plants under Domestication, Vol. ii. p. 356). In one plant they found that "even 30 grains of pollen did not fertilize a single seed; but when 40 grains were applied to the stigma a few seeds of small size were formed." In another species "a flower was fertilized by three grains and succeeded perfectly; twelve flowers were fertilized by two grains, and seventeen flowers by a single grain, and of these, one flower in each lot perfected its seed; and it deserves especial notice," says Darwin, "that the plants produced by these two seeds never attained their proper dimensions, and bore flowers of remarkably small size."

This law of quantity applies equally to the small proportion of the contagia or infecting particles which is introduced into our bodies and governs the ultimate result. That is to say, on the number of those particles depends the fact of active disease following the introduction of infection. Here again I am able to appeal to precise experiment with the particles in which resides the active principle of a communicable disease. I refer to these particles depicted in the diagram exhibited at last lecture [see Fig. 1, p. 12], which are

seen in vaccine lymph; and which have been demonstrated to be *the* infecting portion of that watery fluid. You will remember that this demonstration was accomplished by separating the clear fluid from the granules. To prove still further that a certain number of these granules are necessary to take effect upon the human body,—that is to say, to produce that mild disease called *vaccinia,* or cow-pox, water was added in certain gradually-increased proportions to vaccine lymph, and the activity or efficiency of the mixed fluid was in each case tested by employing it in the usual way for vaccination. In speaking precisely of experiments with fluids or gases, the quantities employed are called volumes; but, for the sake of simplicity, I shall speak of drops, and if you clearly observe my statements your reasoning faculty will have no difficulty in working out their meaning. A mixture of 1 drop of vaccine lymph to 2 drops of water was *always* successful in communicating the cow-pox. A mixture of 1 drop of lymph to 15 drops of water was *nearly always* successful. A mixture of 1 drop of lymph to 50 drops of water was *rarely* successful. A mixture of 1 drop of lymph to 150 drops of water was *only once* successful. A mixture of 1 drop of lymph to 400 drops of water was *never* successful. To crown this demonstration, the experimenter then took this mixture of 1 drop of lymph to 400 drops of water and injected the whole of it into the veins of a horse, an animal which is equally susceptible with man, and the result was *perfectly* successful. It is quite evident from this last experiment that the vaccine particles lost none of their collective efficiency by their dilution; but that, if by any chance of imperfect mixture, a sufficient number of them had been found together in that portion of the whole diluted mixture in which the experimenter dipped his lancet before vaccinating the child,

then the vaccination would have been once successful; and supposing one drop of the mixture to have been used on each occasion until the whole was exhausted, the vaccination would have failed 400 times. Now, for this diluted mixture of vaccine particles, substitute any other diluted mixture of the infecting particles of those diseases which have been engaging our attention to-night. Let us say, water mixed with the infecting particles of enteric fever or cholera; air mixed with the infecting particles of typhus or scarlet fever; sewer-gas emanating from a defective trap or perforated soil-pipe, and how clearly we can conceive of all the phenomena of infection, how summarily we can sweep aside all those fallacious aspects of the facts and inconsistencies of infection which bewilder the public mind, and are so skilfully used by the obstructors of the details of sanitary work. One assures us that he has drunk the water hundreds of times without injury, another that you may find sewer-gas in every house, and how can you say that in his it has been the medium of infection, while in the others it has proved innocuous, and so with a whole round of doubts and difficulties. Take the case of milk-infection, where by some abominable carelessness of the farmer, or some wilful adulteration with sewage-water, that wholesome fluid has become like the diluted mixture of vaccine particles and water. How many may partake of the mixture and not happen to hit upon a portion of the total bulk which contains a sufficiency of the enteric particles to infect; how many may take just enough to derange their health, to cause a short febrile diarrhœa, just as Darwin tells us, "that the plants produced by the imperfectly fertilized seeds never attained their proper dimensions, and bore flowers of remarkably small size;" and how many may take enough to develop the full-blown and perfect disease—enteric

fever! Are the failures in any one of these illustrations any argument against the allegation that the successes were caused through the agency of the water, or the sewer-gas, or the milk? Endeavour to take a firm grasp of these experiments with vaccine lymph, and the mere suggestion of the fallacy will seem absurd and childish.

Another fact in connection with this law of quantity or dilution in regard to those infecting particles is established by precisely similar experiments with the lymph of sheep-pox. It was proved that dilution diminished the chances of infection, just as with vaccine lymph, but that the lymph of sheep-pox would, so to speak, stand much more dilution than the lymph of cow-pox, without being reduced below the infecting strength. While 1 drop of cow-pox to 400 of water produced a mixture which would not take, 1 drop of the lymph of sheep-pox to 500 drops of water produced a mixture which took 13 times out of 21 trials, and even 1 drop to 10,000 of water took once out of 20 trials. The inference is plain. The infecting particles of different diseases are thrown off in different degrees of concentration; therefore they can tolerate different degrees of dilution before they are reduced below the infecting strength. It is obvious also that the physical properties of the medium by which they leave the infected organism, and the physical laws which govern the medium to which they are imparted, must both influence the chances of the infecting particles in each disease being reduced below infecting strength before coming in contact with organisms in health, but open to infection under appropriate circumstances. The combined effects of these and similar laws form the basis of such rough practical expressions as these—the conclusions which grow up in the mind from observation of multitudes of individual facts of infection,—the intensity

of the infection of small-pox and of scarlet fever; the mildness of the infection of typhus in large and airy houses, and its virulence in close and crowded rooms; the rapid and wide stretch of the infection of enteric fever by water or milk; its slow and limited range by the air, and its inertness by ordinary contagion.

I have spoken of the contagia as they are produced in nature, in the form of new secretions, as in vaccine lymph or small-pox virus, both of which exist in little vesicles or containing sacs or bladders, or as admixtures in the natural secretions or excretions, as in the breath and cutaneous exhalations of typhus, or the discharges from the bowels in enteric fever. The infecting unit in all cases is the solid, visible, and sometimes readily separable particle. The facts stated as to the fertilizing action of pollen grains, which are the units of the fertilizing infection, suggest the question whether, so to speak, the energy of the contagia is not unequally subdivided in diseases, whose contagia are of the vaccine or pollen type, as distinguished from the anthrax or fungus type. That is to say, is it not the case, that besides being more concentrated in the infecting secretions, say of sheep-pox than of cow-pox, the particles may not each singly contain a greater bulk of infection in sheep-pox than in cow-pox? Chauveau, whose beautiful experiments and investigations provided the material of my remarks, believes that the varying energy of the contagia, so far as he has studied them, depends entirely upon the concentration of the particles, and it must be admitted that this is sufficient to explain all the phenomena of infection. But we cannot take up the particles of cow-pox and apply them in increasing numbers, noting the point at which they become effective, and as I stated, this has been done with pollen grains, and it has been found that

different pollens fertilize in different numbers. Analogy therefore would lead us to expect that the same physical condition of varying subdivision and varying bulk of the active particle may exist in disease-particles as in pollen grains. Some experimental support to the soundness of this analogy is afforded by that interesting disease hay-fever. The particles which produce hay-fever are undoubtedly the pollen grains of plants, especially of plants belonging to the order *Graminaciœ* or Grasses. Few individuals fortunately are susceptible to their action; but those who are have been proved by Dr. Blackley (who is, fortunately for science, personally susceptible), by experiments of the most exact kind, to owe their ailment to the influence of various pollens. He tells us that "the pollen grains of different orders of plants vary much in size and weight; in some cases not being more than one-twentieth the size or weight of others. This circumstance, however, does not directly affect their power of producing hay-fever. The size of the pollen grain has no relation to the intensity of the symptoms, *when equal quantities by weight are applied.* A large pollen grain may produce a mild attack, whilst a smaller one may produce much more severe derangement." (Experimental Researches on the Causes and Nature of *Catarrhus Aestivus*—Hay-fever or Hay-asthma—by Charles H. Blackley, M.R.C.S., 1873, p. 88). It is obvious that the chances of taking hay-fever from the pollens of different plants will very materially depend upon the size of those pollens. If the same law applies to the particles of the contagia, then a similar additional element of complexity will be introduced into the risks of infection. This however is a digression, for which I must ask you to excuse me on the ground of its great theoretical interest.

A close and thoughtful study of the phenomena of nature in almost any department discloses to us the fact that a common method of working out her ends is to proceed under the general guidance of some vast and comprehensive law, which is directed in its details by innumerable subordinate laws to the ultimate result. This fact is really the explanation of much that we are prone, rashly and ignorantly, to call chance. No one can read the beautiful details of observation, accumulated for example, regarding the fertilization of flowers, and fail to have the conviction of this truth forced upon his mind. There is the great law of conveyance of the pollen grains to the flower and to one particular part in its complex organization. Under the shadow of this law, and constantly governed by it, are all the little artifices of nature—which is a pagan way of saying the special providences of the Divine Artificer—the winds, the waters, the unconscious insects, the attraction of honey, the repulsion of bitter secretions, the sensitive petals and pistils, and all that infinite diversity of mechanical contrivance which prevents here and promotes there the great process of fertilization, so that from an apparently confused cloud of chances and risks comes each several result. The individual phenomena of infection are worked out in this way. The fertilizing or infecting element must reach the person to be infected, but it does so by various channels, and the chance of reaching the person in such a condition of concentration as to be effective is controlled by the law of quantity or dilution. But this by no means exhausts the concurrence of events required for the propagation of disease in the individual, or of conditions which may modify the proportion of successful infections. In the individual there is that varied and numerous class of qualities or circumstances which are embraced within the scope

of the word *susceptibility.* In the largest sense, this susceptibility includes the restriction of certain infectious diseases to certain species of animals, suggesting the existence of a soil or appropriate breeding-ground in the tissues of one animal which does not exist in the tissues of another. It includes also those conditions of climate which limit the infectious diseases peculiar to each species, to those only which inhabit certain countries. But the facts more commonly involved in the idea of susceptibility are such as these —age, sex, physical changes in the body of a permanent kind, arising from previous attacks of the same disease, or of a temporary kind arising from over-fatigue, starvation, and like circumstances. As to *age,* there is the class of infectious diseases which are specially designated—the Infectious Diseases of Childhood. Not only are children more susceptible to take those diseases, but the proportion in which children are present in a population, determines, other circumstances being equal, the susceptibility of that population. Out of the same number of trials or definite attempts at infection with scarlet fever, measles, or hooping-cough you will have a much larger proportion of successes in a community with a high birth-rate, than in a community with a low birth-rate. The most remarkable illustration of susceptibility depending upon age is furnished by the contagia of enteric fever. "Persons under thirty are more than four times as liable to enteric fever as persons over thirty" (Murchison), and it is very rare to find a person suffering from this disease, who is above fifty. Go back for a moment to our former facts as to the unequal distribution of particles in a fluid, and the chances of escaping infection in the use of it. Take the case of contaminated milk, and you will see how much this element of age in the persons exposed to infection

will further complicate the ultimate phenomena of successful infection. Out of a succession of families in a street, you will probably have one or two young couples with few or no children, several in the prime of life with large families ranging in age from 5 to 15 or 20, and a few elderly or aged persons whose families have hived off. The milkman goes faithfully round them all, and distributes his fluid, and his particles of infection; but the people with the grown-up families are all infected, not one family escapes as a whole, though some members may, while there is not a single case in the families of the elderly people; and, very likely, misled by the impunity with which they have used the milk, they are thorough sceptics as to "the milk theory," and become very anxious about their drains.

Susceptibility as modified by *sex* is a fact of but limited scope, and is mainly important in reference to women after childbirth. In that condition they are excessively susceptible to scarlet fever; but to this I shall allude in my last lecture. The fact of *having at a former period been infected* by any one of those diseases either makes the person absolutely insusceptible of taking on the infection again, or makes it much more difficult to accomplish and unlikely to happen. Therefore a population which has once been traversed by an epidemic will not be capable of sustaining another epidemic of the same disease for several years. In the case of epidemics of children's diseases they recur at short intervals, and are never entirely absent, because the fields on which they flourish are never exhausted. Those which chiefly affect adults have longer periods of intermission. Everybody is aware that besides those permanent changes in physical condition, the body may be under the influences of *temporary changes of condition* which exalt or depress its susceptibility—such

changes for example as are associated with over-fatigue, starvation, and the like. Indeed there seems to be a certain degree of *in*susceptibility which may be acquired by prolonged exposure to minor degrees of infection. At anyrate I do not know what other interpretation we can put upon the fact that country people transported at once from the luxurious air of the country into the midst of a town are much more susceptible to town diseases than thoroughbred town's people of the same age, and apparently otherwise alike. We know that people may learn to fatten upon arsenic, and by usage adapt themselves to a dose of poison, or degree of intensity of noxious circumstances which would at once prove fatal to anyone abruptly subjected to them. In like manner, I suspect that the specific particles of disease form so large an element in the daily air and food of us poor town's folks, that in the long-run we may swallow a good many more than our country friends without sustaining any injury.

LECTURE III.

EPIDEMICS: THEIR GROWTH AND GENERAL PREVENTION AND CONTROL.

(10th December, 1878. Bailie Mowat in the Chair.)

Ladies and Gentlemen,

In my last Lecture I spoke to you of the Breeding-places of Infectious disease in this city; of the individual infected as the breeding-place of those infecting particles which, conveyed to other human beings by certain carriers, set up in their bodies the same disease; and of the controlling laws in accordance with which, and directed and modified by which, the fact of infection takes place. Before leaving this general survey of the phenomena of infection, I wish to direct your attention to that interesting, and in some practical aspects, important interval which comes between the fact of infection and the first manifestation of the symptoms of disease. When two inorganic substances, whose conjunction will produce certain phenomena, are brought together, the phenomena are produced at once. The moment a hot poker touches cold water, effervescence begins and steam is thrown off; and even when applied to a living structure, the same instant effect follows. But with poisons, which must be absorbed, and obtain intimate entrance into

living tissues, there is a distinct measurable interval between the bringing together of the poison and the structure and the first signs of mischief. This interval between the fact of infection and the first symptoms of disease in the case of the contagia is called the period of *incubation,* or hatching, the term being derived from the brooding of the hen upon her eggs. Another word, viz. *latent,* is also frequently used, the idea being that the activity of these particles is dormant, or hidden; but incubation is the better expression of the two. The poison in the case of infectious disease is living, and although no outward signs of life are manifest after its introduction into the body, any more than in the egg until the chicken forming inside has advanced considerably in its development, there is beneath this seeming quiescence a steady, continuous process of multiplication of vital particles, until at last the point is reached when the healthy functions of the infected body are interfered with. The disease becomes manifest in the special symptoms which enable the observer first to suspect, and then to distinguish, or *diagnose,* as it is termed, the disease. When an ordinary poison has been administered, there is no increase or multiplication of the original quantity. The dose of arsenic or opium must be absorbed and diffused in the blood, and the time taken up by this process may quite properly be called the *latent* period, but that is merely an extension of the time employed in mixing the dose in the cup, out of which it is drunk, and the original amount of the poison is not increased. In the case of the poison of small-pox, measles, scarlet fever, and such diseases, it is from the outset actively developing, and as it develops, the particles are being diffused and distributed throughout the body. Here, again, you will recognize that we have to do with a phenomenon which is not strange

but familiar to us in the behaviour of all seeds. The farmer scatters his seedcorn over the field, and when we see the blades springing up, we know that if we wish to ascertain when and by whom the first step towards the production of the crop was taken, we must go back some days in our investigation. This is precisely the circumstance in which it is of practical importance that we should understand the general features of this period of incubation of infectious disease; and not only must we remember the general fact, but we must recognize and learn the peculiarities of the seeds of each disease in respect of the length of this period. Just as the seeds of different plants differ in the duration of the latent period, so do the contagia of different diseases.

I may illustrate these statements by reference to the phenomena of vaccination, or the introduction of the infection of Cow-pox, which many of you have had an opportunity of observing. The day after the physician has vaccinated a child, you can see merely the scars left by the lancet in the skin, but next day these scars have become red, and by the third day a close examination discloses the beginnings of the vesicles, or little, bladder-like bodies, which continue to grow, and finally produce by the eighth day the large, pearly-white, vaccine vesicle, which shows that the whole constitution will soon be brought under the influence of this mild disease, which we substitute for the formidable disease Small-pox. In the case of Anthrax, that disease of cattle to which I have so often referred, you may see on that diagram [see Fig. 2, p. 14] what is going on in the body of the animal during the period of outward quiescence which comes between the infection with this fungus—the *Bacillus Anthracis*—and the first symptoms of disease: these spores germinate, grow,

and pass through the stages of their short life, ending in crops of spores which again germinate, until at last the whole blood is infected, and the animal feels ill. Although we cannot describe with the same preciseness the behaviour of the original infecting particles in the infectious diseases of man, there is no doubt they are similarly active during incubation. The length of this period differs even in the same disease, apparently according to the channel by which the person is infected. The Anthrax spores, if inhaled, seem in a few hours to spread through the system, as we can readily understand when we remember that in the fine network of the lungs the whole blood will be brought in contact with them. If, on the other hand, they alight upon the skin, and penetrate alongside the roots of the hairs, and by other natural openings or by minute abrasions obtain access to the tissues, several days are spent in a *local incubation.* You can see the nest, so to speak, in the form of a boil or carbuncle which grows up in the skin. From this visible place of incubation these spores, after a few days, invade the body, and so establish the constitutional disease and produce death. Continental surgeons tell us that the only chance of saving the unfortunate patient is, if possible, to cut out this boil, in the hope that the nest may be removed before the brood has commenced to wander from it over the body. It is well known that the infection of Small-pox, if introduced like that of Cow-pox, by inoculation, as was done before the days of Jenner, establishes the constitutional disease in about half the time which intervenes if it is caught in the ordinary way by accidental infection through the inspired air. Various facts, with which I need not trouble you, enable us at any-rate to surmise that the incubation of other diseases is similarly influenced. Unfortunately, the nest or place of

incubation is not external and accessible, but internal, in the blood, otherwise we might literally *cut short* the disease. We know of no method of doing so, and there is nothing for it but to await the onset of the active symptoms. When these appear, it often happens that the patient or his friends seize hold of some trifling occurrence lying nearest to the first sensations of illness, and regard that as the cause. The more ignorant the people are, the more ridiculous and inadequate the supposed cause may be.

I think we have now spent sufficient time over what may be called the analysis of Infectious Diseases, over the phenomena of their propagation, as exhibited in the infected individual, to enable us with intelligence to consider the *growth or structure, and general prevention and control of the Epidemic.*

In Darwin's great work on "The Origin of Species by means of Natural Selection" I find the following statement: "We may confidently assert that all plants and animals are tending to increase at a geometrical ratio,—that all would rapidly stock every station in which they could anyhow exist, and that this geometrical tendency to increase must be checked by destruction at some period of life" (6th Ed., p. 52.) If I were asked to express in the most precise terms the law of the development of infectious diseases into the epidemic condition, and the rule of sanitary work which the conception and admission of this law as a fact in nature necessarily suggests, I would adapt this statement of Mr. Darwin, thus:—We may confidently assert that all infectious diseases tend to increase at a geometrical ratio,—that all would rapidly become epidemic in every station in which they could anyhow exist, and that this geometrical tendency to increase must be checked

by destruction and obstruction directed to all the conditions of their life.

Geometrical progression, as many of you know, is the increase of numbers or units at a fixed ratio. Thus 1, 2, 4, 8, 16, 32, 64, 128, is a series of numbers obtained from unity by successive multiplications by 2, which is called the ratio of increase. The higher the ratio the more rapidly do the successive products of multiplication grow. Thus, if the ratio be 3, you have this series, 1, 3, 9, 27, 81, 243, 729, 2187; if the ratio be 5, you have this series, 1, 5, 25, 125, 625, 3,125, 15,625, and 78,125.

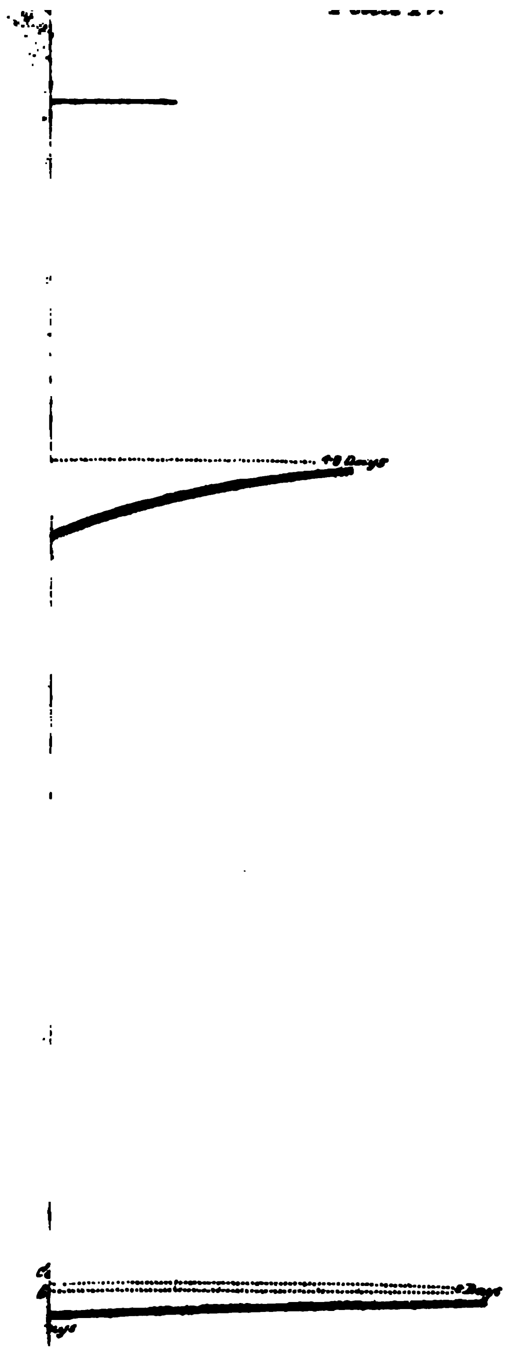
Now, suppose the unit to be a human being infected with one or other of these diseases, and living, say in Glasgow. Notwithstanding the influence of those natural restrictive laws of dilution, or the quantity of the special contagia necessary to infect, susceptibility of the individuals exposed to infection, and the antagonism of those forces of nature which destroy or limit the tendency to geometrical increase, still the fact of this tendency remains. As the average result, without deliberate interference for the destruction or obstruction of this tendency, there will be a geometrical increase of the disease. Still further, comparing one disease with another in the light of the special characteristics of each, which I have in these lectures endeavoured to explain, it will be observed that the tendency to geometrical increase is stronger in one disease than another; that is to say, the average ratio of increase of one disease will be 2, of another, 3, of a third, say 5.

This is a difficult subject to follow and understand, but it is of so much importance that you *should* understand it, that I have endeavoured to construct diagrams which will exhibit, in so far as is possible, in a material, visible way, those abstract

expressions of fact. These diagrams show the average geometrical growth of epidemics of scarlet fever, enteric fever, and cholera, in the special circumstances favourable to the growth of each, and as modified by their special laws of growth. Perhaps it is scarcely necessary to remark that no epidemic actually does assume the exact form depicted in those diagrams; but the only way to clearly grasp the phenomena of nature, is to construct the simplest expressions of their laws, throwing aside, for the moment, all accidental and irregular interference with their normal progress. I have endeavoured to work in one or two of the most important of these irregularities, as I shall afterwards explain, but meanwhile we must think only of the pure, and so far theoretical, case.

The vertical height of those diagrams represents time, a certain number of days on the scale of two inches to three days.* This is intended to give expression to the incubation period. The black dots stand for cases of disease, for infected individuals. We begin in each case with one infected person. Each successive row of dots represents a new crop of infected persons, and the interval between the successive, gradually extending rows exhibits in a rude way the interval of external quiescence between the reception of the poison and the commencement of its activity, and therefore of the power of communicating the infection. Look first at the Scarlet Fever Diagram [see Plate IV.]. The incubation period of scarlet fever is on the average with great constancy six days; therefore the space between each development of cases measures four inches. This diagram may be taken as typical of the progress of typhus, small-pox, measles, and hooping-

* The scale in the Plates is of course much less, and is indicated on Plate V.



Sanitary Department,
Glasgow March, 1879.

cough, as well as of scarlet fever, with this difference that in the same spaces of time, advancing at the same ratio, these diseases would not extend so rapidly, for this reason; the period of incubation is longer, ranging from about ten days in the case of measles to fourteen days in the cases of typhus and hooping-cough. The most moderate ratio we can take is two, that is to say, to suppose that each case of scarlet fever produces two other cases. This falls much short of the possible rates of development whether of scarlet fever or of any one of these diseases of which I have said it is typical, in peculiarly favourable circumstances; much short, for example, of the probable rates in a susceptible population, living in the flatted tenements of Glasgow. Yet you observe that in seven weeks, from one case of scarlet fever at this very moderate rate of geometrical increase, you would have 256 cases. On the same supposition, in from ten to fourteen weeks you would have the same number of the other four diseases. But imagine one of those favourable irregularities of development to occur. Suppose one of that last crop of 256 cases of scarlet fever to be the child of a dairyman; suppose that this child is allowed to run about among the milk tins, or to be employed in distributing the milk among customers. Then infecting particles floating in the air or dropping with the scales of skin from the arms of the child as he or she carried the cans of milk along the street, would at once be committed to that potent carrier of the contagia, milk, and within one week you might have as many cases of scarlet fever produced, as in the normal circumstances of progression had been produced during the whole preceding period of six weeks. This is represented by the cloud of dots over the uppermost line in the diagram. A case of small-pox treated from beginning to end in a crowded house on a common stair,

from beside which women went out shopping or gossiping with their neighbours, or girls to a mill or a warehouse, and men to their daily employment, would inevitably give rise to a similar epidemic outburst. And so with any one of those diseases in similar specially favourable circumstances.

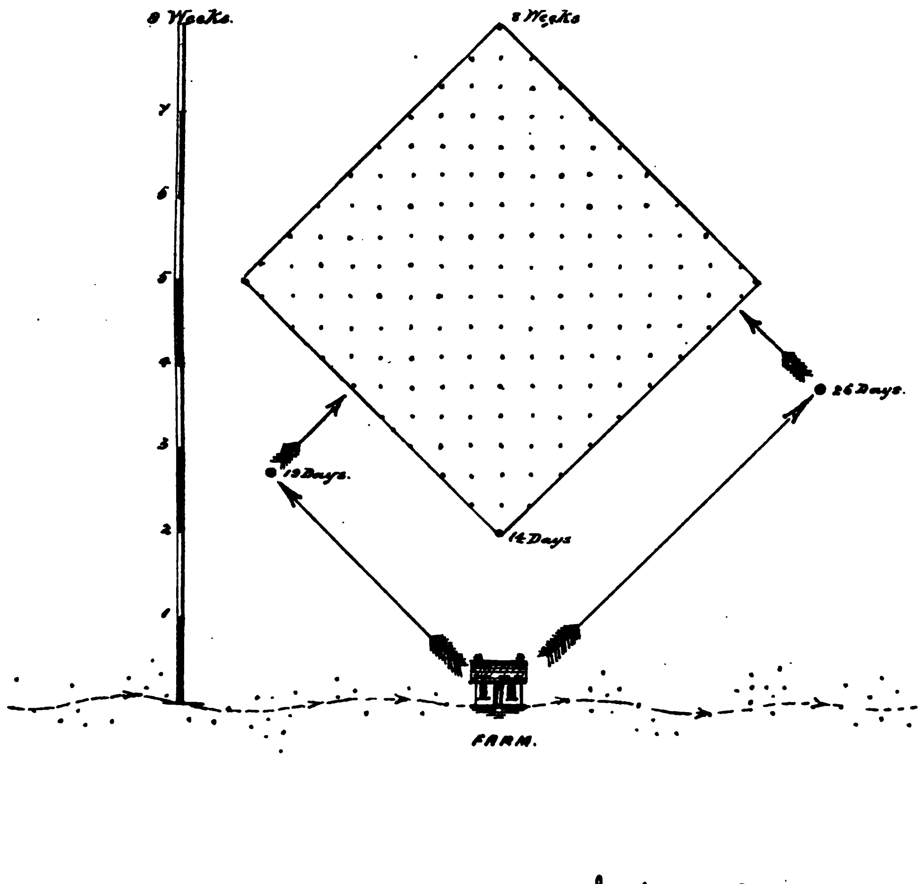
Turn now to the Diagram marked Cholera [see Plate IV.]. There you have a disease, not like the others, propagated by contagion, in the etymological sense of the word, but by the grand public carrier of the contagia—a contaminated water-supply,—say the water of surface wells in a village where there is no system of drainage, and the domestic slops are thrown out about the doors, and the more solid and compact filth is collected in middens. Or say that the water-supply is like that of the greater part of London at the present moment, drawn from a river which receives the sewage of thousands of people. The incubation period of cholera is very short—say about 48 hours on the average, and the ratio of geometrical progression may be taken at the moderate figure of 5. Then in these circumstances, from one case of cholera whose discharges had soaked into the wells or impregnated the water-supply of the city, in eight days, as happened in several villages in Fife in the year 1866, every house in the village would be invaded, and, as happened in the East-end of London in the same year, thousands of the inhabitants would be swept away, for in the main to take cholera is to die of cholera.

Now turn your attention to the last Diagram with which I shall trouble you [see Plate V.]. It represents the epidemic of enteric fever, which was set agoing in Glasgow and Hillhead about this time last year. Enteric fever is essentially a chronic disease in cities, where the water-supply is good; that is to say, it prevails *sporadically*, as we say, in scattered cases, without traceable association of case with

Plate V.

Diagram shewing growth of an Epidemic of Enteric Fever out of ordinary sporadic case occurring at a Dairy Farm.

Time 8 Weeks.



Sanitary Department
Glasgow March, 18

case. This is represented by the straggling, irregular succession of dots distributed across the lower part of the diagram. You observe they are placed at broken intervals, with here and there a group of three or four dots, cases appearing in houses whose internal drain connections are defective, or where, although there are no such connections at all, the inhabitants are untidy and careless in their daily habits. This chronic prevalence of enteric fever is not confined to cities, but unfortunately exists in rural districts. In the case in point one such straggling case appeared in a farm house, where the water-supply was bad, and the general arrangements also very bad. The incubation period of enteric fever is extremely variable, but averages probably 21 days. In 19 days another case appeared at this farm steading, and in 26 days a third. These are indicated by three dots. But in 14 days a group of three cases was developed in a west-end family, who were supplied with the milk from this distant farm house; and within six weeks from that date, or within eight weeks from the appearance of the first case at the farm, at least 166 persons were laid down with enteric fever in this community and in the neighbouring burghs. Nor was the area of infection, over which the contagia developed in this remote country place from this single case were actually distributed by these peculiarly favourable conditions, limited to Glasgow. As you may remember, several of the infected persons were students of the University, and they went home and lay down, and in many cases died, here and there in the three Kingdoms—in the remote Western Islands of Scotland, in Dublin, and in the South of England. There is therefore scarcely any limit to the linear distance to which the infecting products of a single case of infectious disease may be carried. The agency of milk is special and comparatively

rarely pressed into the service of these diseases; but the infected person has the power of locomotion. The period of incubation in each disease is that within which this power may be exercised, and the distance to which the infected person may carry the disease before it becomes active, is bounded only by the rate at which during that period he may travel. Even with such a rapidly developing disease as cholera, a man has been known to catch the infection in Vienna and reach London before he sickened. I have seen in Glasgow a case of small-pox the contagium of which was acquired in Paris, and another in which it was brought from Upper Canada. You may gather from such facts of what practical importance it is to remember the existence of this period of incubation, and also to know something of its duration in the disease which may be the subject of investigation.

Before an infectious disease has attained to sufficient epidemic prevalence to attract public attention, it has usually gone far beyond the stage in its geometrical progression depicted in those diagrams. As time passes the persons attacked in the earlier series have recovered, so that they do not remain before the public eye as they do before your eye in the widening rows of black dots. The degree of fatality of the special disease to a large extent determines the precise point at which alarm is raised. Such a fatal affection as cholera causes immediate excitement. The half of those attacked during the whole course of an epidemic die, but at the outset the mortality is much higher: therefore the very name of cholera causes apprehension. But in the case of the other diseases, the deaths do not accumulate nearly so quickly, so that alarm is not taken until they have been for some time progressing quietly and unobserved. Therefore

the popular point of view of an epidemic is the reverse of the scientific, of that which is presented to you to-night. The popular aspect of an epidemic is bewildered and confused. The threads of connection of case with case are inextricably entangled, and practically lost. There are hundreds or thousands of sick people, and the effect is so universal that the public lose their grasp of, and confidence in the sufficiency of the cause to which science or intelligent knowledge firmly adheres. It is then we hear of epidemic constitutions, pandemic waves, and all those mysterious and unprofitable conceptions which are begotten of ignorance and terror in the human mind. But unless I have totally failed in my treatment of the phenomena which have engaged our attention in these lectures, I shall be much surprised if upon your minds the most wide-spread and alarming epidemic should henceforth produce any such effect. You must always think of those diagrams, which if they end in hundreds or thousands of cases, invariably begin with one. This is the scientific aspect of epidemics, contrasted with what we may call the superstitious and ignorant; for ignorance is the soil in which superstition flourishes. The scientific aspect not only inspires hope and confidence, but imparts precision and effectiveness to our actions. Superstition aims its blows at ghosts and phantoms, but science lays its axe to the substantial root of the epidemic growth. To abandon metaphor and speak plainly, no matter at what stage of this geometrical progression the disease in hand may be, it is against the individual case, the units of the disease, we must direct those measures of destruction and obstruction which will cut short this progression. Each case in the series of hundreds or thousands possesses the same power of progression as the one at the very beginning of the series. Sooner or later this

power of progression will, even without artificial interference or control, by simple exhaustion of the susceptible persons in the population, taper off and finally die out in a descending series, ending as it began—in one. But by interference on well-ascertained principles, we may precipitate this natural event; and it is equally certain, that by the timely exercise of this interference directed to the primary cases, we may make the growth of the epidemic impossible. This at any-rate must be our aim, and I shall now proceed to show you how to carry it out with success; how to prevent, or at least control, the growth of epidemics.

First of all I must assume two things. The carrying out of any systematic work implies an instrument or agency duly fitted to carry out that work. The exercise of any public function in a community implies that there is a public body, endowed with sufficient intelligence and armed with sufficient authority to perform the duties of that function thoroughly. While I make the assumption that there is such a public body to see to the employment of proper measures for the prevention of epidemics, I must assure you that in regard to Scotland, excepting within our burghs, it is a mere assumption. In the rural districts the authority is vested in Parochial Boards, and however strange it may seem it nevertheless is the fact that the local administrators of the Poor-Law, whose burdens are very much the creation of epidemics and ill-health in general, are essentially unfitted to discharge the duties of a Public Health administration. As presently constituted, rural Parochial Boards are generally acknowledged to be ill-adapted even for the proper administration of the Poor-Law. No doubt if they were brought by a Poor-Law Amendment Act to a higher state of efficiency for the discharge of their primary functions, they would also become more intelligent

and effective guardians of the public health. But my own opinion is that Poor-Law administrators and Poor-Law officials are essentially unfitted for the happy and successful performance of the functions of a local authority under a Public Health Act. Sometimes the very talents and attainments which constitute efficiency for one purpose make a man proportionately unfitted for another. I believe it is so with those who carry out the Poor-Law Act. They exist primarily for the benefit of a class, of one element in society. Their duties towards that class are laid down in the hard unyielding lines of law. Whether the applicant for their assistance appears before them in sickness or in health they must be satisfied that the person belongs to this class. The decision of this point implies minute enquiries, disclosing all the painful facts of human weakness—vices, crimes, misspent lives, neglected duties, deceptions—all which are things of the past when you have to deal with present, active, disabling disease, but nevertheless on these depends the decision of the prime question of the Poor-Law—is this person a proper object of relief? Now, evidently, this is not the attitude in which to approach disease of the infectious kind. While the Poor-Law Inspector muses the fire burns. Even although he acts under an entirely different law, viz., the Public Health Act, I cannot believe that for one five minutes he can be the doubting, suspecting adept in cases of disputed settlements, and in the next five minutes deal with disease, as such, frankly and in the broadest view of the public interest, and so pass with equal efficiency through all the hours of his official day, changing his colours, so to speak, like the chameleon, into conformity with the varying shade of his surroundings. So much for what astronomers call the "personal equation," the errors peculiar to and constant in the individual

observer. But it is even more important that, under whatever name or aspect, no person should, simply because of infectious sickness, be brought into contact with the Poor-Law; and the prospect of so being brought into contact with it has been found in Glasgow and in all cities to be enough to create obstructions and difficulties which are fatal to the efficient care of the Public Health. The conception of prevention from the Poor-Law aspect, as regards pauperism, is worked out by repulsion and obstruction applied to the individual who alleges destitution. The conception of prevention from the Public Health aspect, as regards infectious disease, is worked out by attraction and encouragement applied to the individual. The Poor-Law official waits for the applicant; the Sanitary official must go and look for him. You must in the former case deter from and discourage the tendency to appeal to the resources provided by assessment. You must in the latter case encourage and even compel instant appeal to those resources, and that in the interest of the public. A certain disgrace, therefore, surrounds the pauper. He is deprived of his rights as a citizen in the exercise of the franchise for example. On the contrary, it is a public duty and a merit to accept the aid of the Public Health Department. Especially in the matter of hospital treatment, in the great majority of cases the necessity or propriety of it arises not from the wants of the sick person, but from a regard to the welfare of the community. The man who suffers from typhus or small-pox may enjoy in his own home every requirement of sickness, and yet he must be compelled to go to hospital for the common good. As a matter of fact, I ascertained many years ago when in charge of the fever wards of the City Parish of Glasgow that in one epidemic only 8 per cent., in another only 5 per cent. of the

patients under my care had ever been in the Poorhouse before. Why should the 92 or 95 per cent. have been pauperized? Many of those persons, no doubt, were on the verge of pauperism, but many more were not so, but were urged to hospital for the public good by the sanitary staff. Still worse for the public was the fact that numbers would not enter the parochial hospital, and that for reasons which we must all respect. Happily all this is at an end now in Glasgow. The sick of infectious diseases are treated in hospitals supported from the Sanitary Assessment, and the distinction between pauper and non-pauper is in this class of sick people unknown. The result is that consistency and general efficiency in the control of epidemics exist in Glasgow, so far as it is embraced by the municipal boundaries. For an example of the opposite of all this, arising from the persistence of defects which we have long surmounted, I may refer you to London. Here you have an immense community, the unity of whose interest in a sanitary aspect is completely shattered by its subdivisions under the jurisdiction of vestries; and by the allotment of the hospital treatment of infectious diseases to the management of the Boards of Guardians under the Local Government Board. What is found to be essentially bad in cities can never be proved to be good and efficient in country districts. The reason why so little is heard of the defects of the system in the country is simply this, that the resulting evils are not condensed so as to compel attention, and especially that our country friends are easily pleased. Above all things they value a quiet life. For the same reasons I object to the police being in any way associated with sanitary functions. Crime, compulsion, and punishment, as well as pauperism, ought never to be connected with local sanitary functions in one official organization.

under the pressure of some dire necessity, our ancestors have been forced into an enlightened measure, which the departure of those extreme circumstances has permitted us, their descendants, to forget. I was much interested, some time ago, in reading a volume of the Burgh Records of Glasgow to find that, so far back as 1574, more than 300 years ago, in a code of most excellent and complete regulations "for awaye haldyng and preservation of this gud toun" from the "Pest" or plague, which were unanimously passed by the Provost and Bailies of that day, the following item:—"It is statute and ordanit, that gif ony persone or persones, indwellaris in this toun, happins fra this tyme furth to fall sick, that the maister of the hous incontinent cum to the visitors and sercharis of the gait, or ony of thame, and shew the samyn, that thai may be sichtit; and gif ony persones happinis to deceis in ony hous within this toun, that the maister of the hous sall cum to the visitouris appoyntit for sichting thairof or thai be wyndit, *under the pane of banishment.*"—(Burgh Records of Glasgow, 1573—1581. Maitland Club, p. 29.) I may further remark that the authorities of that day had also a special provision for the "Breeding-places of Disease." The last item in those ordinances of Lord Provost Boyd and his worthy colleagues is to this effect—"Ordanis the Schulehous Wynd and all the wennallis to be *simpliciter condampnit and stekit up!*"

You will observe that our ancestors in this good town were so determined that no case of plague should escape their notice, that they ordained that *all* cases of sickness should be reported, and they threw the responsibility of reporting upon the master of the house. I do not intend to suggest details of procedure, but it seems to me this was a very wise provision. Very probably in the changed circumstances of

modern city life, the responsibility would be more secure, and the observation of the law more easily enforced if the medical attendant were required to write in a prescribed form, to be handed to the householder and by him lodged with the authorities, a certificate of the nature of the case. There can be no doubt it is a mere question of time when some such enactment shall become the law of the land. Meanwhile it is satisfactory to find that in this, as in all intelligent measures for the promotion of the public health, our towns are leading the way. In our own neighbourhood, Greenock and Dundee, and in England, Nottingham, Bolton, Burton-on-Trent, and Jarrow have voluntarily imposed upon themselves this duty. There will, therefore, be no lack of precedent or of experience to guide us in details, if Glasgow should at an early date determine to follow their example. Should this be attempted, I claim from you your concurrence and support; and what is good for the town cannot be bad for the country. Indeed; we townspeople must insist on this, among many other protective provisions, being introduced in a new Public Health Act for Scotland.

But you may wish to know how at present the Sanitary Authorities obtain their information of cases of infectious disease. Here again we have been anticipated by our ancestors. I have known discussions as to where and when the practice of house-to-house visitation was introduced, the credit being claimed for different localities as a thing of modern date. In Glasgow, as you may have observed from the above quotation, there were, 300 years ago, public officers appointed called "*Searchers,*" to each of whom a special district was allotted, within which they went from house to house searching for the sick. This is precisely the work done by the Sanitary Officers in Glasgow at the present day. I find from a return furnished by Mr. Macleod, your Sanitary

Inspector, that during the last five years above 250,000 such domiciliary visits have been made by his officers every year. This results in the discovery of many cases of infectious disease of which we should have remained entirely ignorant; but still the greater proportion of the cases in the better parts of the town never are disclosed to us unless they end fatally and are registered as deaths. I submit this ought not to be. Judging by the amount of good which ensues upon the knowledge of those cases, which are laboriously sought for and discovered (about 80 visits are made for each case discovered), good in the shape of advice given, abuses prevented by the prohibition of the use of public wash-houses, of children going to school from infected houses, and in many other ways, besides removal to hospital in certain instances, I am sure if one could extend similar offices to all cases, the result would be so satisfactory that we should all be amazed at our neglect of the salutary and simple provision of compulsory reporting. This is how we endeavour in Glasgow to overcome the defects of the law. But how do the Local Authorities in rural districts act? They maintain a dignified inactivity. They get their knowledge of the prevalent infectious diseases in two ways—by the information pressed upon them by a few enlightened and painfully conscientious medical men, and from the outcry raised in our large towns when the inhabitants find that they are being poisoned by cases of disease existing miles away in the Bæotian paradise of those rural Sanitary Authorities. When thus aroused and galvanized into an activity which is so foreign to their nature, they meet and relieve their feelings in strong expressions about the impertinent interference of the Medical Officer of Health and Sanitary Inspectors of those troublesome towns. Perhaps they prove to their own satisfaction

that "the first case" came from Glasgow, forgetting that even if it came from the moon, their simple duty is to adopt such precautions as will terminate the sublunary career of the disease in the locality upon which it alighted.

Having discovered your case of infectious disease, I must admit that there is a vast interval between the most perfect theoretical mode of dealing with it, and the closest approach to this theoretical mode which is practicable under the necessary conditions of modern city life, and under the still greater restrictions which are imposed by the circumstance that it is with human beings and not with the lower animals we have to do. In a city of which three-fourths of the inhabitants live in one or two apartment houses, it is quite obvious that nothing short of removal of all cases occurring in such houses to hospital would meet the fullest requirements of the case. With adults this does not imply an amount of interference with the natural feelings of mankind, to which it is impossible to conceive that the population in some far distant Hygeia or Utopia may submit. Small-pox, typhus fever, cholera, and perhaps enteric fever might under those circumstances be gathered into the perfect isolation of a hospital. Indeed the two former diseases are, in the majority of instances, so removed, and are so in an increasing proportion; but the large and very fatal item of infectious diseases whose chief victims are children it is quite vain to hope so to seclude. The public official in dealing with these is at once met by the most difficult of all opposition to resist and overcome—the feelings of parents. There is no part of his duty so painful and so delicate. That which is right in the abstract becomes at once impossible to carry out in practice and in detail. I believe that in Glasgow the authorities have done more than in any other community, to encourage and gently to compel and

educate the poor into the acceptance of hospital treatment for their children. Indeed I am not aware that, except in the town of Greenock, anything has been systematically done outside of Glasgow to promote this desirable preventive and life-saving branch of sanitary work. With great liberality in the interpretation of their legal responsibilities, your Local Authority have permitted the sanitary officials to encourage the use of their hospitals for the infectious disease of children by admitting the mothers of young children, there to nurse their own families. This is a most natural arrangement; and I recommend it to the attention of the authorities in other towns. But after all, and no matter how far we may press in this direction, the entire suppression of those diseases of childhood is not to be hoped for even by the most sanguine. The heart is stronger than the head, and in regard to those physical diseases, as in regard to many of the moral diseases which affect mankind, and are the puzzle and vexation of philanthropists, they will remain as a penalty attached to our free-will and reason, and even curiously inwrought with our virtues and graces. But let this be understood, the blame does not lie at the door of sanitary science. We know exactly how scarlet fever, measles, and hooping-cough could be stamped out, or at least made as rare as typhus, small-pox, and cholera. If they are not, it is simply because you will not permit us.

I have already shown you how practically important a knowledge of the nature and duration of the period of incubation which precedes the actual outbreak of infectious disease is in enabling us with great certainty to hark back to the date of the actual occurrence of infection. I have also stated that this is the peripatetic period of those diseases; that is to say, the interval during which the patient, or the person who

is about to become the patient, may move about, and transport the contagia into distant localities. When, therefore, a case of infectious disease has been discovered and isolated, it is highly probable that in the bodies of some members of the same family the same disease may be *incubating.* They are in perfect apparent health, but still the contagium may be only masked. A most scientific method of meeting the requirements of such a case is afforded by the powers conferred upon Local Authorities to provide accommodation for the as yet healthy inmates of an infected house. They may be removed to what is called a Reception-house, and there provided with clean clothing (even allowed to prosecute their daily avocations, if they have any), and watched for the first symptoms of sickness. The majority, perhaps two-thirds, never take ill, but the other third, instead of wandering about or developing the disease anew in the crowded house, perhaps lying there unnoticed for days, are at once transferred to the hospital. I find that, although different diseases have different periods of incubation, on the average a residence of 14 days in this reception-house carries the person beyond the time when any of those diseases will become active, if their infecting particles are present in the system. That therefore is the regulation period of residence.

I have said that those healthy persons who have been removed to the reception-house are provided with clean clothing. When an infectious disease enters a family and has existed for a few days, what are the phenomena of infection which we have to encounter, each in its own appropriate way. Let us go over them one by one. (1.) There is the sick person giving off the contagia. Remove him to the hospital, and the arrangements there are such that all future infection is prevented. (2.) There are the healthy persons who may have

the contagia incubating within. Remove them to the reception-house. (3.) There are the infecting particles which passed from the body of the sick before his removal. These retain all their deadly power after his removal, and it is of little use to remove him unless they are attacked. They exist in the bedding and clothing both of the sick and healthy; attached to the walls and crevices, and lurking in all the dark and dirty corners of the house; and in the ashpit or midden. Just in proportion as the bedding, clothing, and house are, in the ordinary sense of the word dirty, will they be infected. The necessities of the case in respect of this class of phenomena are more complicated, and therefore cannot be so simply and easily met. Very many of those people have no changes of clothing. Therefore, unless you get such to the reception-house, and give them clean clothing to wear while their dirty suit is being washed, it never can be washed at all; and in any case there is no possibility of their bodies being washed except by the aid of an institution. As it is only in a very small proportion of cases that the reception-house is resorted to, seeing we have no compulsory powers except in rare circumstances, I am satisfied that at this point our preventive measures often break down.* This is the hole through which the contagia creep occasionally and elude the meshes of our net. You go to a house, you remove the patient, you fumigate it, and wash all the clothing and bedding; but when the family walked out to enable the disinfectors to carry out their process, they carried on their backs probably as much infection as would replenish the earth although the seeds of the disease

* The Greenock Police Act (1877), Section 199, gives discretionary power to the authorities to remove parties to the reception-house by warrant, whenever that may be thought necessary for the prevention of disease.

had been everywhere else extinct. This is a defect for which the only remedy would be to give the Local Authority power to seclude such people for twenty-four hours to enable their clothing and persons to be properly washed. Observe that the people to whom I refer are always dirty, grossly and undeniably dirty, and as I said before, to dirt no mercy should in any circumstances be shown; above all, certainly not in those circumstances, when a portion of their dirt is infectious and dangerous to the community.

To meet all these necessities the Local Authority must have a washing-house of their own. They must collect all the bedding and clothing every morning, and return it clean and dry the same night, because the majority of the people to whom these articles belong cannot go to bed until their bed-clothes are returned. The contents of all straw and chaff mattresses must be burned, and replaced with clean straw and chaff. Flock mattresses, when dirty, must also be destroyed. This is a most important item in the work of purification. Those ancient mattresses are the abode of all the plagues through which a long line of ancestors has passed, whence they sally out upon the rising generations. Burning is the only process of disinfection to which they can be successfully submitted.

You have probably been expecting me to say something about Disinfection, whereas I have spoken only of washing. Now, disinfection is a good and important process, and every Local Authority ought to have a disinfecting apparatus in which to heat up hair and feather mattresses, and other articles which cannot be washed, to 200° or 250°F., and so destroy the contagious particles. But I say *let everything be washed that will wash*, provided the washing is effectual, in a special washing-house, equipped with modern appliances,

and especially with vats in which the articles may be boiled by the direct action of steam. The practical experience of the Sanitary Department of Glasgow is, that the infection of all the infectious diseases known to us is effectually killed by exposure to this treatment for twenty minutes or half-an-hour.

We have now attacked all the hiding places of disease in the inmates and furnishings of the house. There still remains the house itself. There are cracks and crevices into which only air can penetrate, and in which dirt and infection lurk. To reach these recesses it is necessary to "fumigate the house," as the process is called. Chlorine gas is set free from suitable materials by a staff of men, who close up all chinks in doors and windows, and leave the apartment for an hour under its influence. They then return and lime-wash or size-colour apartments for which that treatment is suited, as in almost all small houses. Paper ought to be *scraped* off and renewed. When the ashpit in the court-yard is emptied, then we have completed our work of extermination and purification, according to the present light of scientific sanitation.

I can assure you, ladies and gentlemen, that this house-work is not only the most pleasant, but it is also, I believe, the most profitable department of sanitary work, measured by the good which it effects. To-day you have the dirty wretched-looking house, and the person sick of fever, scarcely visible in the grimy dark and dirt; to-morrow the sick person is transferred to the comforts of a hospital, the house is clean, the mattresses are renewed, and the bedding, though it may be ragged, has a sweet and wholesome look. Why! such an event is a blessing. It starts those poor people afresh as it were, relieved of all the burden of their past untidiness, and with a practical lesson before them of the beauty of clean-

liness, which must help to raise the standard of their endeavour.

I have not in this lecture troubled you much with figures, but I am anxious that you should have some idea of the magnitude of those precautionary measures in such a city as Glasgow. You will therefore permit me to conclude by informing you, in so far as mere figures can, of the nature and extent of the work done on the lines laid down in this lecture during the last five years. Excepting the infectious diseases of children, no infectious disease became widely epidemic during that time. I give you the average yearly work of that period in round numbers.

Each year 263,000 house-to-house visits were made, in the course of which 3120 cases of infectious disease were discovered: 1500 were removed to hospital; 260 healthy persons were accommodated in the reception-house; 119,000 articles of bedding and clothing were washed; 3700 mattresses were burned (either wholly or their contents alone) and renewed; and 5300 apartments were fumigated, the greater number of which were also lime-washed and size-coloured. Besides the cases of disease discovered there were as many more reported through the School Board, by medical men, or by the relatives and neighbours of the sick, who remained at home, but under supervision, and for whom some of the washing and cleansing detailed was done. I need not add that these figures represent but one item of the whole work of the Department.

LECTURE IV.

HINTS AS TO THE MANAGEMENT OF INFECTIOUS DISEASE AT HOME.

(17th December, 1878. Councillor W. R. W. Smith in the Chair.)

Ladies and Gentlemen,

In my last lecture I endeavoured to impress upon you the fact that epidemics can be prevented or controlled only by directing the appropriate measures against each single case. Each single case has in itself the same tendency to spread by geometrical progression, which, being unchecked in the first scattered cases in which all epidemics begin, produces the epidemic expansion. I sketched for you in outline the nature of the measures which the Local Authority ought to bring to bear upon each case, and explained how those measures were guided, so as to compass all the directions in which the spreading tendencies work themselves out into fulfilment. I pointed out that in by far the majority of the cases of every kind of infectious disease in a community like Glasgow, the only perfect way of meeting all the conditions of success in stamping out the disease was to begin with the transference of the patient from the house to the hospital. A properly situated, properly planned, and

properly managed hospital is a place which not only provides for the safety, and comfort, and proper treatment of the sick person, so far as his private interests are concerned, but it is also a place which, in the fullest sense of the word, isolates him. The word *isolate* is etymologically the same as the word *insulate*. It means to place the patient on an island—a place cut off from the mainland of everyday life; so that, when he is removed thither, the Local Authority become responsible for the public safety as well as his private safety, and are therefore relieved of all further anxiety as to this tendency to geometrical progression. The measures of purification and destruction of the infection thrown off before the removal of the patient are carried out once for all in the house from which he was removed; but in the hospital, during the whole course of his sickness, this infection is being thrown off, and the internal economy of the hospital is carefully arranged to neutralize and destroy that infection. As a matter of fact, however, the proportion of the total number of cases of infectious disease which arise in any community which is treated in this theoretically perfect way is very small. I gave you my reasons for believing that with regard to those infectious diseases whose victims are mainly children, it will always be the case that they are treated at home. But however this may be, the fact remains that upon heads of families and other relatives at present fall those grave responsibilities which in a few cases are assumed by the Local Authority. It is, therefore, of the very utmost importance that the public at large should have some clear idea of the nature of those responsibilities, and of the best means to adopt to enable them to meet them successfully, or to attain the greatest degree of success which individual circumstances permit.

First of all, let me claim and assert on behalf of the Local Authority their right to supervise the precautionary measures which are or ought to be adopted in every case of privately-treated sickness of the infectious sort. It is the assertion of this right which is the practical reason for demanding that all such cases should be reported to the Local Authority. The mass of the healthy population have such a pre-eminent and preferential interest in the adoption of these precautions that the slightest reflection will at once convince all right-thinking and not utterly selfish people that they can never be, with due regard to this preponderating interest, carried out properly but at sight of the Local Authority. What is done in the case of fire? Although it may be only a wooden shed or a bundle of straw which is in flames, the interest of surrounding proprietors is so great, that the proprietor is not permitted to choose whether or no he shall accept the services of the public fire-master and fire-engines. They are set to work without consulting his wishes, and he must even contribute to the expense of extinguishing the flames. On the other hand, the proprietor has a right to the services of those public officials and apparatus. He pays for the current expense of their maintenance, and has a right to share their advantages. So it is with hospitals, washing-houses, disinfecting appliances, and the skilled advice and assistance of the sanitary staff. You all pay for their maintenance; you have all a right to their use and employment on your behalf; and on the other hand the general public have a right to see that you, when the occasion arises, avail yourselves of those public provisions, and to insist that you avail yourselves of them, in the face of all private reasons that may be urged for being left alone and uninterfered with. Therefore, as citizens, being within the jurisdiction of an intelligent and

properly-equipped Local Authority, you must remember that behind all the private arrangements which I am about to suggest, you have the resources of the Local Authority to supplement your private efforts, and over all you must constantly have the supervision and guidance of the officials appointed by the Local Authority in the public interest.

The first thing to be thought of in connection with the occurrence of sickness of any kind in the household, is the room in which the patient is to be treated. The choice of, and the arrangements within, a sick-room are of great practical importance to all sick persons; but in the case of a person sick of infectious disease they are also of supreme importance to the attendants, the inmates, and the public. Infectious sickness seizes us in our habits as we live, and if these be defective, *then* at anyrate it is impossible to hide their defects. Bedrooms are too often planned and furnished like drawing-rooms, or apartments where sickness and its frailties would be out of place, whereas a little sober thoughtfulness, such as one has a right to expect from rational beings who ought to be able to see the end from the beginning, would make every bedroom a suitable sick-room. More or less of this practical forethought is possible to every one, but I at present speak more particularly to those who live in large houses, and whose circumstances put no restraint even upon their fancies. To such I have much pleasure in recommending a little book published by Macmillan & Co. in their "Art at Home Series," and called "The Bedroom and Boudoir," by Lady Barker. It is quite a matter of taste whether you accept or reject the authoress' preference for the Queen Anne style of furnishing and decorating, but there is no room for difference when she insists upon ventilation, or gives expression to such wise and truthful maxims as these:—"People do

not half enough realize . . . how the emanations from the human body are attracted to the sides of the room and stick there. It is not a pretty or poetical idea, but it is unhappily a fact. So the only thing to be done is to provide ourselves with walls which will either wash or clean in some way, or are made originally of some material which neither attracts nor retains these minute particles."—(p. 4.) Again she says—"I dwell on the walls of the bedroom because I believe them to be the most important from a sanitary as well as from a decorative point of view, and because there is really no excuse for not being able to make them extremely pretty." —(p. 8.) As to carpets Lady Barker writes—"What I should like to see, especially in all London bedrooms, is a fresh, inexpensive carpet of unobtrusive colours, which can be constantly taken away and cleaned or renewed, rather than a more costly, rich-looking floor-covering, which will surely in time become and remain more or less dirty."—(p. 19.) She does not like the iron bedstead, but merely for reasons of taste. She prefers the low, hardwood, polished bedstead without upholstering. As to curtains she says—"Screens on either side of the bed are a much prettier and more healthy substitute." In the same sensible spirit Lady Barker will guide you through all the appointments of the bedroom, always combining the most refined taste with a thorough appreciation of the fact that every bedroom is a possible sick-room.

Just in proportion as you have followed these sound principles in providing your bedrooms when in health, will you find it easier to adapt them to the exigencies of sickness of all kinds when it comes. Yet, I need not tell you how very far from this state of preparedness or ready adaptability are the sleeping apartments of people of every station. For

the benefit of those who are in this predicament among the more wealthy, Lady Barker has an equally valuable chapter on "The Sick Room," in which, with reference to ordinary sickness, you will find hints and directions which go far to meet even the most exacting requirements of infectious sickness. "If I am in authority in such a case," she says, "I turn all gimcracks bodily out, substituting the plainest articles of furniture to be found in the house."—(p. 97). Again—"All woollen draperies, curtains and valences should be done away with in a sick-room;" and so in the course of her chapters she picks up a variety of details in the same thoughtful and sensible manner. It has often occurred to me to ask, why do gentlemen who build houses with billiard-rooms and smoking-rooms, not also add an hospital-room—a room at the top of the house, with smooth impervious walls and ceilings, and floors of oak, well waxed, with iron bedsteads, polished hardwood chairs, and, in short, equipped so that any one, child or adult, attacked with infectious disease could be treated apart from the general economy of the house. Such surroundings could with the least possible trouble be purified at the end of the sickness, because in fact with ordinary care they are self-disinfecting, throwing off the infection as the duck's back does water. But in place of such a sensible provision, how often have I seen, let us say, a child in the height of scarlet fever tossing on a feather bed in the middle of a broad bedstead, padded at top and bottom, covered with a down quilt, perhaps closed in with heavy damask curtains; on the floor a massive carpet; stuff-bottomed chairs, padded couches, well-stocked wardrobes, in short, every kind of device in furniture and decorations to catch and retain the volatile infection. To carry out cleansing and disinfection after the recovery of a patient treated under such

circumstances is impossible. Only a universal burning of the contents of the room would warrant us in being confident of success.

People living in the enjoyment of such luxurious facilities for the proper disposition of the infected sick, wilfully sacrifice all their advantages, and could easily adopt any suggestions we choose to make, even the most exacting; but when I set myself to put these suggestions in order, I am at once reminded that the great majority of the inhabitants of this city, or we might say of this country, cannot possibly adopt such suggestions. Still, in the full knowledge that this is the case, I think it better to sketch in outline the arrangements proper for the home-management of infectious sickness, even though the result should be an ideal, impossible of attainment by the majority. This is the only way to give full expression to general principles, and that being accomplished, it will remain for each one to follow these principles as far as possible. There are also flagrant errors which almost anyone may avoid, or at anyrate not unnecessarily exaggerate, and of these I shall specify a few in the appropriate place.

In a self-contained house the sick-room ought to be as high up, and in a flatted house, as far off from the kitchen, as possible. It is obviously absurd to select the kitchen, yet this, in small houses, is very commonly done, apparently because, there, attendance is easier, which it certainly is, but for the very reason that makes the kitchen unsuitable, viz.—that it is in constant use for the common purposes of the household. Free ventilation and exposure to sunlight are essential. The sun's rays have a powerful purifying influence, promoting the destruction of organic effluvia, which the fresh air disperses, and so makes at once less infectious by dilution, and thereby

less able to resist chemical action. Remembering that the patient will throw off the solid particles which convey infection, during the course of his illness, the room ought to be deliberately prepared so as to afford no hiding-places for these particles, and so to minimize the final processes of cleansing and disinfection. Like Lady Barker, you should "turn all gimcracks bodily out, substituting the plainest articles of furniture to be found in the house." The carpets must be lifted, not only in the room chosen, but in those on the same landing, or, in a small house, from every apartment. If for comfort some patches of carpet are thought to be necessary, let them be old, or such as may be burned at last. Haircloth is entirely inadmissible inside the room, as you may convince yourself by bringing your hand down smartly upon any chair or sofa covered with it, even in the cleanest of houses. All curtains or drapery must be removed, and so with wardrobes or chests of drawers. If these last cannot be stowed away, they should be emptied of everything not required by the sick person. Featherbeds, downquilts, padded and elaborately upholstered bedsteads, are all inconsistent with first principles.

So much for what should not be in the sick-room. The furnishings which ought to be there must, of course, have properties in relation to infection which are of the very opposite kind. I am neither an upholsterer nor a haberdasher, and therefore cannot be expected to fully catalogue and describe for you all the articles which meet the requirements of these general principles. I may say, however, that an iron bedstead, with hair mattress, and straw palliasse, wool-flock pillows, and ordinary bed-clothes, with a varnished or other impervious screen to ward off draughts, will sufficiently equip the bed.

Kitchen chairs can always be had. An iron compound couch and arm-chair, padded with hair, and covered with Russian leather, will provide luxuriously for the convalescent or attendant, while a pillow or a cheap cushion will make the hard chairs more comfortable. The bed should be so placed that the attendant may move freely round it, a position which is also certain to bring it out of stagnant corners into freely circulating air. The ordinary built-in, or concealed, bed is not healthy in any circumstances, and when occupied by an infected patient is simply murderous, both for patient and attendant.

Having got what may be called the still-life of the sick-room arranged to our mind, we must see to the attendance and the general relations of the sick-room to the economy of the house. Here again it ought to be sufficient to lay down principles. All the details must be determined by this simple aim—to cut off the patient as much as possible from all contact, direct or indirect, with the healthy. The nurse or nurses must be withdrawn from the domestic circle; in the choice of their dress they must select material which is close in texture and which will wash without injury. The crockery, crystal, and other table requisites must be set aside and kept apart. Food which has been in the sick-room must not be used by the healthy, whether broken or not, and the attendants ought, for their own sake, neither to eat or sleep, if possible, in the sick-room. The more closely you look into those and other details which arise from the requirements of perfect isolation of sick and healthy, both within and without the limits of the house, the more you will recognize the difficulties which surround the working out of this isolation in practice. Indeed you have only to reflect upon the necessary conditions of domestic and social life in the vast majority

of families to satisfy yourselves that those difficulties are insurmountable. We cannot stop the whole machinery of the life of those families, and that is really what perfect isolation would demand and effect. But it is wonderful what a little common sense, combined with strict conscientiousness, can accomplish in the most adverse circumstances. Yet I must tell you there is no test of common sense, and above all of conscience, so severe and so lamentable and astounding in its results as that applied by the presence of infectious sickness in the household. The sanitary official obtains a naked, undisguised glimpse of one aspect of human nature, which is hidden even from the family doctor, who as a rule is familiar with the weakest parts not only of our constitution but of our moral character. Again and again has it been necessary for me to unveil this "night side of human nature" in defence of official interference in cases in which the private medical attendant fancied that in his instructions he had sufficiently provided not only for the interest of his patient but for that of the public also. It is one thing, however, to give instructions and quite another to have them honestly and sensibly carried out. This is really the secret reason of much apparently exacting interference on the part of the officers of the Local Authority, as well as of the high theoretical standard set up in those requirements of isolation. Their rigid exactness is absolutely necessary to overcome or circumvent that prevailing want of common sense and conscience in the home management of infectious disease, which is so fatal to the public interests.

It may be profitable to look at this matter for a little, because of the opportunity it gives of enforcing first principles, which is the most compact and useful kind of education. The common-sense aspect of infectious disease, wherever it

occurs; is simply that which I expressed in my last lecture by saying—We are not fighting with ghosts or phantoms, airy beings, whose malevolent designs are worked out by tricks, deceptions, and surprises, but against material forms, the action and effects of which are fixed in unchangeable accordance with simple physical laws. Once acquire a general working knowledge of those laws (and it is a duty which every citizen owes to society, if not to himself, to acquire such knowledge), and a man may do many things with impunity, which, done by the ignorant and careless, would be either suicidal or murderous, or both. For example, a man or woman so informed and guided may enter the sick-room and see and speak to the child, sick of some fever, and then go to business, or the workshop, or the factory, and expose no one to any risk whatever, and therefore not be blameworthy. But how many people are there in these circumstances who have the common sense to change their coat or their gown, to avoid sitting on the bed, or fondling the child, or taking it on their knee if it be convalescent? So rare is this power of adapting conduct to the changed circumstances of infectious disease, that on the average of mankind we require to assume that such foolish conduct is the rule, and to enforce precautions accordingly. These are very familiar illustrations of the entire round of the details of isolation. Accordingly, when my opinion and advice are asked on such questions as these—"May some one do something with safety?" or "Such and such were my instructions in a specified case; do you think they were sufficient?" my reply is expressed after this fashion—"The action you describe is of the nature of a scientific experiment. I believe I could carry it out with a successful result—that is, without injury to the public; but if the experiment is to be made by an ignorant person, it will

fail, and the practical meaning of failure is—that the public will suffer."

But what shall we say when we turn to the conscientious element in the problem? The golden rule—"All things whatsoever ye would that men should do to you, do ye even so to them"—if observed with scrupulous nicety by every person who has infectious disease in the house, and even if combined with nothing more than the general conceptions of the nature of infectious disease which are in modern times floating about in the public mind, would go far to render legislation and official supervision superfluous. So far is this from being the case, that promises and arrangements of all kinds, concerning the preventive management of infectious sickness, must be received and criticised under discount, in proportion to the conscientious development of the promiser, and the weight with which the person's private interests seem to tend in a direction opposed to the carrying out of the arrangements. If, for the purpose of illustration, I specify certain classes of people, you must not suppose that all persons belonging to that class are alike to be distrusted. I have no wish to libel any class or trade, but my object cannot be attained without saying that there are at least three kinds of people who must be suspected, because their interests, or what they suppose to be their interests, so frequently come into direct antagonism with the interests of the public in this regard. I mean that numerous class of small shopkeepers who live in apartments in direct communication with, or even in the neighbourhood of, their shops; those engaged in the milk trade; and those who keep lodgers. The business relationships of such persons to the public are such that, so far as the application of the golden rule to those relationships, in the presence of infectious disease, is concerned, they are

utterly demoralized. In the main they cannot be trusted to adopt the very simplest precautions. Concealment is their first resort, to be protected and prolonged by artifice and deceit; and when these are broken through, there is no practical safety to be secured for the public, unless by adopting such measures as will put the public entirely out of their mercy. Legislation is imperatively required with reference to these and other classes of persons who, simply from the manner of their lives or the nature of the articles in which they deal, are placed at central points in the lines of possible transference of infection to the body of society. Still it is but fair, because it is the simple truth, to say that in all ranks and classes of men there is a conspicuous want of conscience in their private dealings with infectious disease.

Let us now return from this long but important digression, to speak a few words about the general daily management of the sick-room. Chemical disinfection of the air of a sick-room during the progress of the sickness is *impossible.* I say so after having myself believed in and practised it; but to attempt it is annoying and troublesome, and to trust to it is to be deluded, and to have your attention diverted from the only efficient mode of disinfection of air, which is dilution and displacement by fresh air. Especially I must characterize the setting apart of cups and plates of Condy's Fluid, and the like, as not only useless but ridiculous. Every bedroom ought to have a fire-place, and the fire ought always to be lighted when the room contains an infected sick person. In warm weather a very slight fire will suffice, and a screen will limit radiation of heat. Even in the smallest houses, by this means, a current will be maintained from the body of the house into the sick-room, and even from open windows,

towards the fire-place. It need scarcely be said that the more tangible and offensive excretions of the sick ought to be removed at once. They become more and more infectious the longer they are retained in the room. The natural offensiveness of such excretions gives us ample warning and direction how to deal with them. *Ferralum* is the name of a disinfecting powder which may with advantage be put into the ordinary vessels of the bed-chamber. It is both a chemically destructive agent, and the oily portion of its composition keeps down offensive vapours by forming a scum or oily pellicle on the surface of fluids. Another precaution which tends to keep the air of the apartment sweet and clean is to see that bed and body linens are changed frequently, and to remove soiled articles at once. As these must be stored somewhere before being washed, I would recommend that a steep be prepared in some convenient vessel, such as a tub or a tin foot-bath, which ought to be kept in the bath-room or some adjacent closet. This steep should be made up in the proportion of a quarter of a pint of pure, transparent, fluid carbolic acid to one gallon of water, and into this these soiled articles ought to be at once plunged. This prevents decomposition, and prepares the articles for the boiling process, which ought to form a part of the washing process of all infected clothing. The only other department of the daily management of the sick-rooms is the dusting down of the furniture and sweeping up of the floors. This ought to be done carefully, at least once a day, and the dust *ought to be collected and deposited in the centre of the fire,* there to be consumed. To convince you that in doing so you are actually destroying the most dangerous portion of the *débris* of a sick-room, I would ask you to look at the diagram upon the wall, in which a friend has copied for me some of

the small particles and bodies collected from the air of a London Hospital, and drawn as they were seen under the

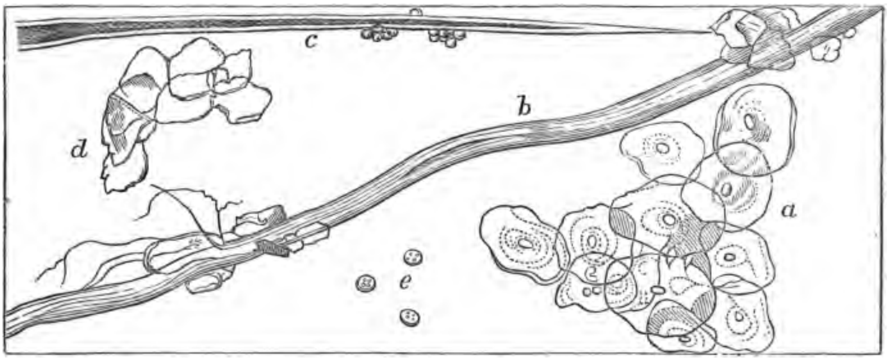


Fig. 6

microscope. These particles were gathered from the air, but they tend gradually to subside, and ultimately constitute the most dangerous part of that dust to which I refer. There are cells which an anatomist readily identifies as epithelial cells from the inner surface of the mouth *(a)*, and others which come from the skin *(d)*, and are indeed part of the scaly *debris* of the human skin which is so much increased in scarlet fever, but is even in health always being thrown off, though in lesser quantity. There are also pus cells from suppurating sores *(e)*. The long thready bodies are fragments of hairs *(c)* and of linen fibre from clothing *(b)*. These are not in themselves dangerous, neither in truth are the mere scales of epithelial cells; but they come from the human body, and if that human body is infected, they may carry the infecting particles, or, at least, wherever they are, there may those infecting particles be also. These may be too small to be visible, and they are not sufficiently well known to be recognized and sworn to, even when visible. You will observe, however, that both the hair and the linen fibre

have small fungus-like bodies adherent to them. This is how they were actually seen in the dust from the air of this hospital; so that you must picture to yourselves all the dust of an infected bed-chamber as possibly infected. Even those particles which are in themselves harmless may be acting as rafts, floating about, burdened with the dangerous material.

Just in proportion as the bedroom has been prepared in accordance with the principles which I have laid down, and as the daily *regime* of cleanliness and purification described has been faithfully carried out, will the final disinfection, at the conclusion of the illness, be simplified and more certain to succeed. Repeated baths, begun during the convalescence of the patient, soon remove all infection from the body. He then puts on a clean suit and walks out to join the rest of the household, leaving behind him all remaining sôurces of danger, which can be treated in detail with precision and certainty. If, however, there have been no such sensible preparation, and no such daily care, the holes in the meshes of the disinfector's net are wide, and failure probable. Rather than go over in detail the work to be done at the conclusion of a case of private sickness, I shall describe how a much more difficult task was actually accomplished, viz., the disinfection of a hospital ward after prolonged use for the treatment of small-pox, typhus fever, and scarlet fever, so as in each case to prepare it for the treatment of some other disease. The hospital was a temporary one, constructed of wood, floored and lined with ordinary deal planking, the joints of which were not close, but, on the contrary, gaped more or less throughout. There was no paint or varnish. The task was therefore most difficult, *the* most difficult which can be conceived; and this is how we set

about it. All the bedding and clothing was simply washed as usual, part of the process being half-an-hour's boiling. The straw in the mattresses was burned, and the ticks washed; so with the pillow-ticks, the wool being subjected to the fumes of burning sulphur for some hours on one occasion, and on another burned and renewed. The window-blinds and cords were taken down and burned, and replaced with new ones. The iron bedsteads and all other articles of furniture were taken out, and thoroughly washed with carbolic acid soap, and the bedsteads repainted. The ward itself was then attacked. First every part of it—roof, walls, and finally floor—was scrupulously dusted down, and the dust collected and burned. Then every part of it was washed down with carbolic acid soap, and, *while all the surfaces were wet*, all openings having been previously stuffed or papered up, sulphur was burned until it was impossible, looking from without, to see across the ward, owing to the density of the fumes. The ward was left for a night in this state. The fumes of burning sulphur are sulphurous acid gas. The object of applying it while the surfaces were wet was to ensure its absorption by the water, and its destructive action on any particles lurking in the cracks. If those particles had been dry, the gas would not have penetrated into their substance. After these various processes had been carried out as described, I have again and again used the same ward for treating scarlet fever after typhus, small-pox after typhus, typhus after small-pox, and once for treating cases of ordinary sickness after small-pox. In my earlier attempts there was twice a failure, and these were very instructive, as most failures are, when thoroughly investigated. Once several small-pox patients took typhus, and what was the cause? The wool of the bolsters had been fumigated with sulphurous

acid, but the infecting particles were dry—a condition in which all infecting particles live longest, and resist almost any process of disinfection. Ever afterwards we burned the wool. It is cheap, and therefore I advised you to use it for pillows in home treatment; and now I add, destroy it after it has served its purpose. The other failure was shown by the infection of one patient with small-pox. For some time we were puzzled how to account for this mishap, but at last suspicion was directed to a screen covered with green baize. The patient lay next the ward door. To protect him from draught, the nurse had imported this screen, which had been in use in the treatment of small-pox, and the cloth had not been stripped off and burned, according to orders—an illustration of the flaws which a little thoughtlessness or negligence will make even in the best schemes, especially in dealing with a disease whose infection is so adhesive and long-lived in the dry state as that of small-pox.

Asking you to take these model cases of disinfection, accomplished under the most trying circumstances, with these illustrations of the failures to which all such processes are liable, as examples for your guidance as to what you have to do and what to avoid doing in private cases, I shall conclude with some remarks on the individual characteristics of the more common infectious diseases. I have hitherto spoken of them as a class. In the hands of the majority of mankind it is better to lay down rules for universal application. The average intelligence of the public is not equal to the task of discriminating between one disease and another, so as, with safety, to apply exceptional treatment. *Negligence, and especially untidy and dirty habits, obliterate all distinctions in the infectiousness of those diseases;* but where there is cleanliness and intelligence, it is possible, so to speak, to take

more liberties with some infectious diseases than with others; and they can be classified also according to the direction in which danger is specially to be anticipated and obviated.

Typhus is essentially the attendant of personal uncleanness and overcrowding. The infection passes off by the skin and breath, and consequently impregnates the clothing and the air both directly and indirectly. The odour of typhus resembles that of rotten damp straw, and is readily recognizable. The general relation between overcrowding and typhus was most conclusively proved by Dr. Gairdner in 1866, when the last great typhus epidemic appeared in Glasgow, and was demonstrated by statistics to prevail in exact proportion to the number of overcrowded houses in each district. By repeated investigations since, I have found that from 50 to 80 per cent. of all the houses in which typhus appears are grossly overcrowded. In Glasgow, as some of you may know, we affix a ticket upon small houses, stating how many inmates are permitted. A constant system of night inspection of such houses is maintained, and persons who harbour people in excess of this number are brought before the Magistrates, first to be admonished, and then, if brought up again, to be fined. It frequently happens that persons who have offended in this way appear in our hospitals suffering from a still more severe penalty of their misdemeanour in the shape of typhus. People who live in such houses carry the infection about with them wherever they go. I have known of a dissolute clerk infecting his master; of a shoemaker infecting his employer when delivering the shoes which he had made; of an untidy servant conveying it to her mistress. Yet, by returning to cleanliness, there is no disease which can with such certainty be disarmed and made powerless to injure. Medical men, clergymen, and others, whose

duties bring them within reach of typhus, never communicate it to their families, even when they take it themselves. I have again and again seen such persons nursed with every care, and close, tender, personal offices by their relatives, and yet no instance of the extension of the disease in these circumstances has come under my notice. Copious dilution with fresh air, and frequent changes of linen, completely deprive typhus of its infecting power.

Hooping-cough is a disease to which children are especially susceptible; and the younger they are the more dangerous to life is the attack. This is shown by the fact that the average age of all fatal cases registered in England during 24 years was under two years. Yet hooping-cough may infect persons of the most advanced age, if not protected by a previous attack. When the late Sir David Brewster was 85 years of age, I find him writing to Sir William Fairbairn a letter, in which he says—"I have also been an invalid like yourself, but from a different cause. When on a visit to my daughter in the autumn, I caught hooping-cough, *a horrid complaint*, from the effects of which I am not yet free"—that was six months later.—(Fairbairn's *Life*, p. 426). Little is known of the nature of the infection, excepting that it exists in the mucous secretions of the lungs and air-passages, and may be imparted to the clothes of those who nurse the patient. These secretions are infectious from the first, before it is possible to say that the child has not simply caught cold, and, as they retain this property all through the course of this most protracted of all diseases, it is obvious what a potent source of contagion even one case of hooping-cough is, especially when we take account of the fact that the older children may, and indeed must, for their own health's sake, move about in the open air. It is so extremely fatal to

infants, that whatever may be done with elder children, no effort should be spared to keep the younger out of the range of the infection.

Measles and *scarlet fever* are diseases the contagia of which have extraordinary vitality. They seem, indeed, in certain circumstances to have no tendency to die a natural death. Measles resembles hooping-cough in this, that it begins with well-marked catarrhal symptoms, and all the secretions from the air-passages, and even the tears which run copiously from the eyes, are highly infectious. Sneezing is a common symptom at the outset, and this scatters the infected fluids violently abroad. Hence it so often happens that, before the nature of the illness is decided by the appearance of the eruption, and before the sick child can be isolated, the first case in a family of children has infected them all. In scarlet fever, the secretions from the upper parts of the air-passages, the glands in the throat and the nose, become at once infectious. It will be obvious, therefore, that pocket-handkerchiefs in both these diseases must be carefully attended to; and indeed it is better to use rags for the removal of those secretions, and to burn them at once. After these diseases have advanced a few days the eruption appears on the skin. In scarlet fever it is sometimes so slight and transient as to escape notice, but this does not practically diminish the risk of infection, or render caution less necessary when the stage of desquamation or of casting of the skin is reached. When narrowly examined, the measles eruption is seen to consist of multitudes of very small vesicles or microscopic blisters, the watery contents of which have been proved by inoculation experiments to be highly infectious. After measles the skin is shed in a very fine, bran-like dust, but after scarlet fever, in flakes and scales.

Here we have the contagion in that dry condition to which I have already referred as being that physical state in which all infecting particles seem to enjoy the power of almost endless existence—in a dormant state, but always ready, like the seeds of plants, to become active when dropped into a congenial soil. Every infectious disease, both of man and the lower animals, which is known to exist outside its natural breeding-place, the animal body—in articles of dress, in carpets, curtains, in straw, hay, the hides, hair, wool, and other parts of the dead bodies of animals, in stables, byres. &c., &c.—will be found to do so in virtue of the infecting particles being lodged in this dry, dormant state in those various substances and places. The experience of every family doctor will furnish illustrations of the extreme subtilty and tenacity of measles and scarlet fever, which are all easily accounted for by this feature of these diseases—that their poison is lodged in and goes with the *debris* of the skin. Therefore, in their home treatment, it is absolutely indispensable, *firstly*, to prepare the sick-room, by stripping it of everything which can receive and retain these dry particles; *secondly*, to pay strict attention to the daily collection and destruction of the dust of the apartment; and *thirdly*, to oil the patient's body daily, so as to deprive the *debris* of the skin of its buoyancy and volatility. Just to show you how a very small and inadvertent neglect in the carrying out of these precautions may be productive of failures in your efforts to limit the range of the disease in a household, I shall relate the following story in the words of Sir Thomas Watson:—

"Scarlet fever had attacked several persons in a large household. When it was fairly over, the house was left empty, and then (as was supposed) most thoroughly ventilated and purified. *A year afterwards* the family returned to the

house. A drawer in one of the bedrooms resisted for some time attempts to pull it open. It was found that a strip of flannel had got between the drawer and its frame, and had made the drawer stick. This piece of flannel the housemaid put playfully round her neck. An old nurse, who was present, recognized it as having been used for an application to the throat of one of the former subjects of scarlet fever, snatched it from her, and instantly burned it in the fire. The girl, however, soon sickened, and the disease ran a second time through the household, affecting those who had not had it on the first occasion."—(*Lectures*, 5th edition, vol. ii., p. 983). As I told you in my second lecture, women after confinement are highly susceptible to scarlet fever. When seized in those circumstances the disease is always of a most malignant type, and *almost* always proves fatal. It is therefore a wise proceeding, when this ailment breaks out in a family where such an event is impending, to remove the woman at once away from the house. If she attempts to nurse the sick, then the chance is that the seeds of the disease will lurk, in this dormant condition, somewhere or other, and at once develope into fatal activity after the confinement.

Although this is the last lecture of this short course, and although I have now only a few minutes more which I can reasonably ask you to afford me to conclude these somewhat lengthy remarks, I find that my material is by no means exhausted. I must, however, throw aside for the present my intention to take up cholera, enteric fever, and that other disease which is in every one's thoughts at this time, viz., diphtheria; but I cannot let slip this opportunity of saying something to you of small-pox, in relation to vaccination and revaccination, based upon these large coloured diagrams which are displayed upon the wall [see Plate VI.]. These diagrams exhibit

pictorially the results of a very minute and laborious investigation into the condition as to vaccination of 1000 cases of small-pox, which were treated in hospital under my care in the year 1871.

In the first place, let me explain that each of these squares is subdivided into 100 smaller squares, each of which represents one case of small-pox. Therefore every large square represents 100 cases, and the number of the smaller squares, which is coloured black, or red, or left white, expresses accurately the proportion in each 100 (that is to say, the percentage of cases) which had this disease in different degrees of severity.* The severity of a case of small-pox depends entirely upon the extent of the eruption. In this respect, small-pox resembles burns and scalds. Burns and scalds are in general dangerous to life in proportion to the extent of surface of skin which is destroyed or injured by heat. There are three degrees of the eruption of small-pox—the *rare* or *sparse eruption*, in which the papules or pustules are scattered at wide intervals over the skin; the *copious eruption*, in which they are planted closely, but still not so closely as to touch each other or run together; and the *confluent eruption* in which they are so closely situated as to coalesce or run together, and to cover the whole skin, or a large proportion of the skin, with one continuous sore or suppurating sheet of pustules. Of these degrees of eruption, the *rare* is *seldom* fatal, the *copious* is *frequently* fatal, and the *confluent always* puts the life of the patient in jeopardy, and is *very frequently* fatal. In these diagrams, those portions which are white show you the percentage of the cases which had a rare eruption, those portions which are red the percentage

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*** In the Plate the black is also black, the red is represented by shading, and the white is also white.**

which had a copious eruption, and those which are black the percentage which had a confluent, and therefore highly fatal form of the disease. You will further please take note that in the four vertical rows of large squares (each three in number) each square represents one hundred cases of small-pox occurring in persons of the same age. The three groups on your left are all aged below ten years, and in succession towards your right they are aged from 10 to 20, from 20 to 30, and from 30 to 40. None of the patients were older than 40. Looking now at the squares in the horizontal direction, from left to right, you will observe that they again form three rows, each row containing four squares, each square representing groups of one hundred persons at four successive periods of age, advancing by ten years from the youngest to the oldest At the left end of those horizontal rows you will observe certain words written, which describe the nature of the cases represented by each row. The top row shows the influence of vaccination on small-pox "when *well* done," the middle row "when *badly* done," while the bottom row shows small-pox *without* vaccination, or "natural small-pox." Now, I shall not trouble you with figures, though you must remember that this is merely out of regard for your convenience, because these diagrams are not theoretical, not imaginary, but embody observed facts. But lay aside all thought of anything but this—that each of these squares represents 100 cases of small-pox, and the colours show the severity of those cases, black being *very* dangerous to life, red *dangerous*, and white *without* risk. Now let us reason together on what we see. These groups of 100 persons are exactly alike in only one respect, viz.,—that they all have the disease called small-pox. In no one group are the three forms of the disease found in the same proportions. You observe that in several groups nearly

half, in others much more than half, are affected with the very fatal form; while in some groups only a very few have this fatal form, and in one group there is not a single example of the fatal form, and only a very few examples of the form which to some extent endangers life. What is the cause of these differences? Is it age? Take each series of these groups, from top to bottom of the diagram, and you have in each one hundred persons who are alike, not only in having small-pox, but in being of the same age. Yet they differ enormously in the nature of the disease. At each of the four periods of life there is still this most striking difference. But, observe, there is a close agreement between the groups at each age in the manner of their difference. Take these groups of persons who are all under 10 years of age. As you pass from one group to another downwards you find the type of disease worse in the middle group than in the upper group, and worse in the lower group than in the middle group. It is the same with those three groups of persons who are all between 10 and 20, with those who are all between 20 and 30, and with those who are all between 30 and 40—in all, the middle is more severely affected than the upper, and the lower than the middle group. It is, therefore, of importance to ask—In what respect do each of these three groups of persons, who all have small-pox, are all of the same age, but all present the same sort of difference as to the severity of the attack, differ in common? The common difference must be something affecting all the upper row alike, all the middle row alike, and all the lower row alike. At *all* the four vertical series of ages the middle row is infected more severely than the top row, and the bottom row more severely than the middle row. The only quality or property in which every group of one hundred persons in the

top row agrees is this—that *all* were *well* vaccinated in their infancy. The only quality or property in which every group of one hundred persons in the middle row agrees is this—that *all* were *badly* vaccinated in their infancy. The only quality or property in which every group of one hundred persons in the bottom row agrees is this—that *none* of these persons were vaccinated in their infancy. I put it to the reasoning faculty of each one of you—Can you see any way out of this inference from these facts?—*that the vaccination is the cause of the mildness and comparative harmlessness of the attack of small-pox in the upper groups of persons, and that the want of it is the cause of the severity and comparative fatality of the attack of small-pox in the lower groups of persons?* If an agent is asserted to be the cause of certain phenomena, then, if you impair in any way the efficiency of the agent, there ought to be a corresponding impairment in the character and completeness of the phenomena. This crucial test is supplied by the middle row of groups as compared with the upper. The vaccination was *imperfectly* performed in the middle row, and the effect which I attribute to it is *imperfectly* developed—the attack of small-pox was more severe than in those who were perfectly vaccinated, and yet much *less* severe than in those who were *not* vaccinated at all.

But there is more in these facts than this—that vaccination modifies or diminishes the severity of small-pox, even when it has so far failed of its effect as not absolutely to prevent the infection. As in the groups of well vaccinated, badly vaccinated, and unvaccinated persons, you pass from group to group across the diagram, rising in age from the youngest to the oldest, you must at once observe this—that the *well* vaccinated as they become older take the disease in a *slightly*

worse form, the *badly* vaccinated in a *very much* worse form, but those who have not been vaccinated at all are, *throughout their whole life from infancy upwards,* subjected to the very worst, most fatal form of the disease. The result is that when those persons who have been well vaccinated reach the age of 30 years, they still, in only a very few instances take confluent small-pox, while those who have been *badly vaccinated* are almost as liable to confluent small-pox as those who have *never been vaccinated at all.* Again I appeal to your reasoning faculty for the interpretation of these facts, and ask you if they admit of any other interpretation than this—*that the influence of vaccination, well and thoroughly done, extends, with but little loss of protecting power, throughout life; while, if badly and imperfectly done, it is never so efficient in protecting power, gradually loses what protecting powers it ever possessed, and finally leaves the badly vaccinated individual only a little less susceptible than the individual who has never been vaccinated at all?*

Now, assuming that you have been able to follow me thus far, let me endeavour to take you a step further, and to widen the area of our inferences from all these facts. These groups represent persons who have actually, in their several conditions as to vaccination or non-vaccination, been infected with small-pox; but what of those persons who were in the same conditions, who were equally exposed to the risk of infection, and who did not take the small-pox? Can we reasonably believe this influence of vaccination which, in those who *were* infected, was so *potent,* was *impotent* in those who were *not* infected? I answer no. These facts alone are sufficient to warrant us in believing that if we took 100 persons who were in those three categories, as to vaccination or non-vaccination

and exposed all alike to the epidemic influence of small-pox, we should find this to be the result: Of the 100 well vaccinated persons, the great majority would escape scathless; of the 100 badly vaccinated, the majority would be infected; and of the 100 unvaccinated persons, all would be stricken. *Therefore, putting all these facts together, the well vaccinated person is not only likely to take the mildest form of small-pox, if he takes it at all, but he is likely to escape infection altogether; while the unvaccinated person is, in the first place, certain to take the disease, and, in the next, likely to take it in its most malignant form.*

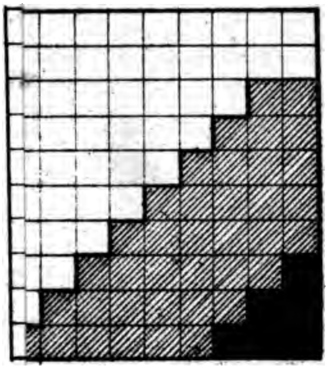
My time is exhausted, and I only ask you to observe the practical effect of these facts, in pointing out to us the most important measures for the prevention of small-pox. The first is, to see that the entire population is well vaccinated in infancy. How do we know that a person has been well vaccinated? By the size and character of the vaccine mark. Therefore I say to medical men—Aim at producing a mark upon the child's arm as large as a half-crown piece; and to mothers, don't grumble at this, as if your child was being disfigured or branded, in place of being shielded from the risk of the most fatal and loathesome of all diseases. The second practical inference is this—Whenever small-pox appears in your household, immediately have every adult re-vaccinated, and any child who does not possess a good vaccine mark, or who has not yet been vaccinated, re-vaccinated or vaccinated, as the case may be. You may isolate, you may disinfect, or in short do anything you please, but if you neglect these precautions, you will utterly fail in preventing the spread of this disease.

Plate VI.

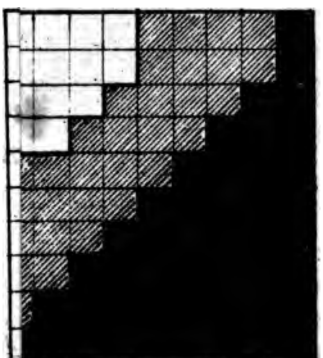
ages: ——

30 - 39 Years.

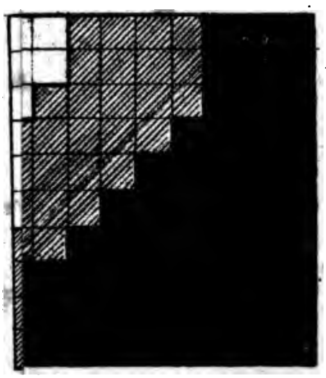
When well done.



When badly done



Not done at all — Natural Small-Pox



Eruption ■

mitary Department
Glasgow. March 1870.

LECTURES BY DR. WALLACE.

LECTURE I.

THE AIR OF TOWNS.

(29th November, 1878. Bailie Thomson in the Chair.)

LADIES AND GENTLEMEN,

IF we consider the essential conditions of existence, not of ourselves alone, but of animated beings generally, we find that we can reduce them to three in number, but all of these are so important that none of them can be dispensed with. First, then, we must have air to breathe; second, we must have water to drink; and, third, we must have food to eat. The thought will naturally arise that there is a fourth necessary condition of existence as regards ourselves—the possession of clothing; but a little consideration will show that this condition is accidental rather than absolute, for the Ancient Britons are said to have been content with painting their bodies, and we are credibly informed by travellers in Patagonia, that, in a climate colder than we enjoy in this country, the use of clothing is unknown. At all events, clothing is a condition of existence that cannot be dealt with chemically, and I shall confine my remarks to air, water, and food; and I will endeavour to show you that not only are these essential to life itself, but that health can be maintained only by breathing pure air, drinking uncontaminated water, and eating wholesome and nutritious food.

In the present lecture I shall treat of air, and the subject is such a comprehensive one, that the difficulty of dealing with it depends, not in knowing what to say, but in selecting the facts necessary for the elucidation of the subject from the vast stores of knowledge which the study of the atmosphere involves.

Like all other terrestrial objects, air may be viewed in two distinct sets of relations to surrounding matter. We might consider it mechanically, both in a state of rest and in motion; we might study its weight, the degree of force with which it presses on the earth's surface, its expansion when its own pressure is removed, its influence on the boiling points of liquids, and many other phases. But these properties, although exceedingly interesting, and deserving of the most attentive study, are not those which claim our attention to-night, and I shall only refer very briefly to them.

The other light in which the air may be regarded is that which refers to its chemical relations, particularly in the phenomenon of combustion, and that modified form of it which maintains the warmth of our bodies; and this constitutes our special subject to-night.

All the objects by which we are surrounded are divisible into three classes—solid, liquid, and gaseous. The solids affect us by their more or less perfect resistance to the sense of touch: we can handle a solid, lift it up, and throw it away; its particles possess so much coherence that it preserves its form. A liquid, on the other hand, takes the form of the receptacle containing it; its particles possess so little cohesive force one for another that it may be poured from one vessel to another, always maintaining, however, a level surface. It is not, however, entirely devoid of cohesion, for in certain circumstances it collects into drops, which approach very

nearly to the spherical form, as we see in the dew-drop on a blade of grass. In gases (such as air) the cohesive force is absent, we have in fact the opposite force, repulsion, exhibiting itself whenever the pressure of the superincumbent atmosphere is removed. We cannot see air—in ordinary circumstances we cannot feel it, it offers so little resistance; and hence arises the fiction of speaking of vessels as being empty when they are really filled with air. A common bottle may be made to illustrate very beautifully and conclusively the fact that air is a form of matter. It is a fundamental law of nature that no two things can exist in the same space at the same time. When a nail is driven into wood, the particles of the wood are thrust aside, and the iron takes up the position they formerly held. So, if we fill a bottle with water, we must at the same time expel the air, and the water will not pour out of the bottle unless air is permitted to enter at the same time.

The density of the atmosphere varies at different altitudes, and at a height of about 18,000 feet, or about 3½ miles, it is exactly half what it is at the earth's surface; in other words, people at that elevation breathe exactly half the quantity of air by weight that they do at the level of the sea. In some of the silver mines in both North and South America, the rarity of the air is such that men can only work a short time: they cannot run, nor undergo any violent exercise, because they cannot get enough of air into their lungs. In some cases the mines are at an elevation of about 15,000 feet. On the other hand, if a man descends in a diving-bell to the depth of 34 feet, the pressure of the water condenses the air to half its bulk, and that man breathes double the quantity of air that he would inhale under ordinary circumstances; and the conditions are such that he cannot

remain for any great length of time in this abnormal state without suffering serious inconvenience. Air is infinitely expansible and compressible, and it is affected not only by strictly mechanical appliances, but also by heat. Air, when heated, expands; and this is a most important property in relation to the subject of ventilation, which will engage our attention further on.

Air is not a single substance, like sulphur, iron, or any of the other elementary bodies; neither is it a chemical compound, like water, common salt, or saltpetre. It is a mixture of various gases, the two most important as regards quantity being elementary, while the others are chemical compounds. The elementary bodies are oxygen and nitrogen, 100 parts of dry, and what may be called pure air, being composed of 21 volumes or measures of oxygen and 79 volumes or measures of nitrogen. The compound bodies are carbonic acid, ammonia, nitric acid, and aqueous vapour. These, unlike the elementary bodies, are inconstant in quantity; but the aqueous vapour averages in this climate about 1½ per cent., and the carbonic acid 33 parts in 100,000. The ammonia and nitric acid exist in quantities too minute to be put in intelligible figures; the proportions are excessively irregular, and one or other may be altogether wanting. Ozone, or oxygen in its more active condition, is also an almost constant component of natural air; for although in many situations and at particular times it cannot be detected, we can generally account satisfactorily for its absence. The proportion which the oxygen bears to the nitrogen in pure air is practically constant in all situations—on land and at sea, at high as well as low altitudes; but all the other ingredients are subject to considerable variations, although, after all, the differences, except in the case of aqueous vapour, are not great, unless the composition is influenced by causes

which may be considered accidental or local, such as volcanic eruptions or proximity to towns or manufacturing industries. Over the sea and for a short distance inland common salt is a constant constituent, although the quantity is exceedingly minute, except during violent storms, when it is sometimes carried several miles inland in such quantity as to be deposited visibly on window panes and chimney stalks. Of course the other ingredients of sea-water accompany the salt, which is the most abundant solid constituent of sea water.

The air may be regarded as necessary to the existence of animals, on the one hand, and as essential to plants on the other. Animals require oxygen diluted with nitrogen—which itself is an indifferent gas, taking no part in combustion or respiration; while plants require carbonic acid, ammonia, and nitric acid. As regards the air of towns, the latter ingredients are important only in so far as they are produced by the functions of animal life; and by their accumulation, together with the products of manufacturing industry and the burning of various sources of heat and light, they render the air impure and unwholesome. According as the air of a town departs further and further from the standard of purity of that existing in the country, it becomes more and more unhealthy, and the aim of sanitary science is to introduce into town life conditions calculated to bring it into some sort of approximation to the degree of purity of the air of the country.

Let us now examine briefly the properties of the chief constituents of air. The most abundant ingredient is nitrogen (so named because it exists in nitre and nitric acid). It is a colourless, tasteless, invisible gas; it does not support respiration or combustion; in fact, its properties are altogether of a negative character, its only use, so far as we can see, in the economy of animal life being to dilute the otherwise too active

oxygen and restrain its energy. It is usually made by burning phosphorus in a bell-jar over water.

Oxygen is perhaps the most interesting of all the elementary bodies, and the study of its properties is important in sanitary science. We cannot take it from air directly, but we can take it from air by combining it with another body, and then liberate it; and it may also be made by heating certain minerals and chemical compounds. I will not trouble you by preparing it before you—I have a quantity of it prepared. It is an invisible, inodorous gas, but not respirable—at least for any length of time; its energy being such that it soon destroys the delicate tissues of the respiratory organs and causes death. Its most marked characteristic is the energetic way in which it supports combustion, and this may be shown in a variety of ways, as in relighting a taper which has been blown out but in which the tip of the wick still remains red; in burning a splinter of wood or piece of charcoal, merely lighted at one point; and in burning phosphorus and iron or steel wire, which consume with great rapidity, producing intense heat and light. Many other experiments might be exhibited, but these are sufficient to illustrate the energy of its action.

While it would not suit us to breathe pure oxygen, nor even an air containing more than the normal proportion of that ingredient, yet any deviation from the natural standard in the way of diminution at once results in a lowered condition of vitality. We are too apt to blame impurities in the air for *all* the evils of overcrowding, and to forget that the very formation of these impurities is accompanied by a diminution of the proportion of oxygen, which of itself is sufficient to account for many of the effects.

Let us see now what combustion is, and what are the products of burning, say, a candle. The candle contains two

elements—carbon and hydrogen—both of which have a great affinity for one of the constituents of air, namely oxygen; and the act of combustion is simply the union of the carbon and hydrogen with oxygen, to form compounds which are respectively water and carbonic acid. If we hold over a burning candle a dry bottle, we observe that it immediately becomes dim from the deposition of moisture, and if the combustion is carried on long enough, the water will collect in drops and flow down. I have here a somewhat more elaborate apparatus, which is employed in testing gas for the quantity of sulphur it contains. In this a small jet of gas is kept burning for about 10 hours, and the quantity of water that collects is often as much as 6 or 8 ounces—in fact, a good sized tumblerful. Now, this water does not exist in the candle nor in the gas, but results, as I have said, from the combination of the hydrogen in these bodies with the oxygen of the air. We shall now carry the experiment with the bottle further: by keeping it over the flame for some time the flame is extinguished, showing that by its own combustion the candle has produced a gas that is inimical to flame. If we now introduce into the bottle some lime water (easily made by mixing common lime with water, and allowing the excess to settle down), the clear liquid immediately becomes turbid—a precipitate of carbonate of lime being produced. The chemical compound which causes the turbidity is called carbonic acid, and is composed of carbon and oxygen. Ordinary chalk, limestone, and the various kinds of marble are all forms, more or less pure, of carbonate of lime, the same compound that causes the turbidity in this experiment. If we collect the precipitate and pour an acid upon it, an effervescence is produced, owing to the carbonic acid coming off, and if the experiment is made in a flask with a bent tube,

we can try the properties of the gas that is evolved. First, we have its power of extinguishing flame; and second, the production of a precipitate with lime water, in which is reproduced the very compound (carbonate of lime) from which the gas is obtained. And here I would have you to remark, that the extinction of the flame in our original experiment does not depend solely upon the presence of the carbonic acid gas, but also, to some extent, upon the diminution of the quantity of oxygen in the air. A candle goes out when about 8 per cent. out of the 21 contained in the air disappears, of which 6 are combined with carbon; and as the carbonic acid produced occupies exactly the same bulk, there is consequently 6 per cent of that compound in the mixture in which the candle refuses to burn. It may interest you to know what weights of the two compounds are produced: A pound of tallow candles gives as nearly as possible a pound of water and 3 lbs. of carbonic acid, in all 4 lbs. of product—showing that 3 lbs. of oxygen have been taken up from the air. The quantity consumed would be 170 cubic feet if all the oxygen were available; but, as I shall show you further on, air is very stifling, and almost irrespirable, when it contains only 1 per cent. of carbonic acid. It follows, that if the candles are burnt in an ordinary apartment, the pound weight would in fact require 21 times 170, or 3,570 cubic feet of air. Ordinary coal gas requires rather more air, weight for weight, than candles.

Now, respiration is merely a modified form of combustion. If time admitted, I could show you various instances of combustion without flame or intense heat; but the fact is, that every act of combustion is simply chemical combination, and every act of chemical combination, no matter whether great heat and light are produced or only a slight elevation

of temperature, is combustion. As I shall tell you more particularly in our Lecture on Food, all our alimentary substances may be divided into two classes—those which go to form flesh, and which contain the constituents of flesh, and those which contain essentially carbon and hydrogen, and which are included under the general term of respiratory food. The combination of the carbon and hydrogen is effected in the lungs, or in the vessels communicating with the lungs, and while we inhale pure air, that which we exhale is loaded both with moisture and carbonic acid. If I take a piece of thick plate glass and breathe opposite it, it speedily becomes dim, and by-and-by drops of water collect and fall down; and again, if I blow through lime water it soon becomes turbid. I dare say I can show you the result in a still more striking manner, by collecting by means of the pneumatic trough some bottles of expired air. The first portion that comes from the lungs, containing, as it does, comparatively little carbonic acid, supports the combustion of a taper or candle, but the last portion contains more than 6 per cent., and immediately extinguishes flame.

The chief causes of the impurity of the air in towns are respiration by the lungs and by the skin, and the combustion of fuel, whether in the form of gas, paraffin oil, or candles, used for purposes of illumination; or coal, wood, or peat, used to burn in fire-grate or furnace, for warming our houses, raising steam, or for manufacturing operations. The atmosphere is in its normal or natural condition at any place sufficiently removed from towns and public works. Wherever the population is sparse the air is pure; consequently, in mountainous regions, as in Switzerland and the highlands of Scotland, or the lake districts of England and Ireland, we experience a

feeling of freshness and exhilaration which we never have in towns. Again, at the sea-side the air is generally speaking very pure. On the other hand, the air is very impure in coal pits when these are, as is too often the case, insufficiently ventilated; in schools, workshops, and very frequently in churches and other places of public assemblage. In private houses it depends entirely upon circumstances whether the air is bad or tolerably good. There are many things which influence the condition of the air in apartments; for instance, a fire produces a current which serves to maintain a certain amount of ventilation, and if the windows are not very tight it is a great advantage. Again, the occurrence of a high wind is advantageous in changing the impure air. But in apartments that are crowded, it is practically impossible to maintain the air in a state of purity, and crowded rooms and tenements are the hot-beds of disease. When the natural proportion of oxygen is reduced to 20 per cent., the remaining 1 per cent. being converted in great part into carbonic acid gas, the condition of the air is something fearful; but it is rarely that it is so bad as that, even in schools, which furnish about the worst examples of the evil effects of overcrowding. I am glad to say that a great improvement is taking place in school buildings, although it must be acknowledged that it is almost impossible to ventilate a school so as to maintain a fair amount of purity in the air. As an illustration of this difficulty, I may mention that in our new University, supposed to be supplied with every modern application of science, the air in some of the class-rooms is often in a dangerously stifling condition. The difficulty of ventilating a building where the whole floor is covered by human beings, as in a well-filled church or hall, is best understood by considering the case of a densely-packed crowd collected in

the open air, when, if the air is comparatively still, and the temperature tolerably high, all the evil effects of over-crowding are distinctly felt by those who are removed a little way from the outside of the circle. If this is the case in the open air, the difficulty is necessarily enormously increased when the crowd is cramped up in a building with low ceiling, and confined there for several hours, as in the case of a concert or public meeting. Even in churches, where the duration of the service seldom exceeds an hour and three quarters, the want of efficient ventilation is often severely felt, and it is a common observation, that members of the congregation who feel no inclination to sleep during the forenoon service, frequently indulge in a nap in the afternoon, being overcome by the imperfect æration of the blood, which results from breathing air deficient in oxygen and contaminated with carbonic acid. I think the importance of the subject can best be brought home to your minds by giving a few statistics. Each person (being the average of both sexes and all ages) consumes at each inspiration 25 cubic inches of air, and breathes 18 times in a minute. The air thus breathed contains 5 per cent. of carbonic acid gas. Now, a person may breathe air containing a ½ per cent. of carbonic acid with impunity, at least for a short time, while a larger proportion is more or less dangerous. Taking ½ per cent., therefore, as the basis of our calculation, each person requires 2½ cubic feet of air per minute, or 150 cubic feet per hour. If a sleeping apartment for 1 person be taken at 1000 cubic feet—that is 10 feet square, and 10 feet high—and with no means provided of changing the air, this space would suffice for 1 person for a period of 6¾ hours; and this, I understand, is something like the space demanded by the police regulations of this city in the case of houses of the lower class. Of course,

the inmates of the houses remain much longer than the time specified, and the air is by no means pure at the commencement of the night, so that the point of danger must be, and in fact is, not only approached, but greatly exceeded. On the other hand, the apartments of the poor are generally far from being air-tight, and much fresh air finds its way in by chinks in the doors and windows, while a like amount of vitiated air is removed by the chimney. Now, we may assume, for the sake of argument, that in a ventilating shaft in the roof of a building, having free entrance of air at another point, the heated air will ascend at the rate of 1 foot per second, or 60 feet per minute. There is very little use in making an exit for heated or impure air unless there is also an opening of equal area for the admission of air from without. The best system of ventilation for public buildings is that in which there are two concentric tubes, the outer one being short for the admission of air, and the inner one long for the outlet of the heated air—for most fortunately the impure air is always heated. I have here a model of the apparatus, which was invented by a Mr. M'Kinnel of this city. There is also Watson's patent, long since lapsed, in which a single tube is divided up the centre, and Muir's, in which a square tube is divided into four diagonally. Some buildings, such as churches, are so large in themselves that the air in the building counts for something, and less air is required to be introduced by the ventilator than is necessary for workshops or schools, where the space is usually so small in proportion to the number of persons present that it may be left out of account altogether. Now, calculated from the data I have given, a school with 200 children, if the air is to be maintained in a moderate state of purity, will require a ventilator for the outlet of the bad air,

supposing it to be square, of 2 feet 10½ inches, or if round, 3 feet 2¾ inches diameter. If an outer tube for the admission of fresh air is placed outside the other it requires to be 4 feet 1 inch square, or 4 feet 6¾ inches diameter, if round. Again, take a church of an ordinary size in large towns, constructed to hold 1500 persons, and making due allowance for the air in the church and the comparatively short time during which the people are assembled: in this case the inner tube would be 6 feet 5½ inches and the outer one 9 feet 1½ inches square; or if the tubes were round, they would be 7 feet 2¾ inches inside and 10 feet 2 inches outside. I do not think there is any church in existence where the ventilation is anything like sufficient, as we can readily test by going in from the open air at the conclusion of the service. If present all the time, the impurity accumulates so gradually, and we become so inured to it by habit, that we do not feel it in the same degree. In a school of the old type, after the day's labours are over, the air is usually so impure that one can scarcely enter without becoming sick and faint. No doubt the schools of the most recent construction are greatly improved, but still ventilation, as a general rule, is far from efficient even in places where we should expect to find it carried out in the most scientific manner—for instance, in such a building as our University. With regard to gas jets, which also exhaust the air, we may safely count each light as equal in vitiating power to three persons. I have said that vitiated air always ascends, in consequence of the heat communicated to it by our bodies or by being burned in gas flames; hence the galleries in churches and theatres are always the most offensive. I illustrate this fact by burning under a bell-jar three candles at different heights, when the top one will go out first, then the middle one, and last of all the one at the bottom. If, after an evening's

sitting in a dining-room, you take a pair of steps and go up to within a foot of the ceiling, you will find the air not only very hot but also frightfully stifling, especially if the gas has been burning for some hours previously.* It must not be supposed, however, that the carbonic acid is the only impurity in respired air, or air vitiated by the burning of gas. As regards the latter, the sulphur it contains is a somewhat serious evil, especially in the case of gas made from common coal, which gives comparatively little light, so that a large quantity requires to be burnt in order to light up a room efficiently; while at the same time it usually contains at least twice as much sulphur as gas made from cannel coal. The sulphur in burning produces sulphurous acid, and this gradually changes to sulphuric acid, which, besides being injurious to health, is also damaging to furniture, books, and all kinds of fabrics, especially those of cotton. It is not surprising, therefore, to find in London dining-rooms and drawing-rooms lighted up with candles or oil lamps instead of gas. Then, as to the air we exhale from our lungs and skin, there are various gases and vapours which, although not easily defined, are really very offensive if breathed over and over again, as is the case in a crowded apartment or insufficiently large bedroom. The measure of these impurities may be estimated relatively by finding the quantity of ready-formed and producible or "albuminoid" ammonia which the air contains, a system of air-testing introduced by Dr. Angus Smith, of Manchester, the chief inspector of alkali works in this country, and applied with some improvements in our own

* A description of Tobin's system of ventilation was given, and that introduced some years since by Mr. Hoey of Glasgow, and the modification of it by Mr. W. R. W. Smith were minutely described and illustrated by experimental results, furnished by Mr. Dobson of the Sanitary Office.

city by Mr. E. M. Dixon, B.Sc. I show you here Mr. Dixon's apparatus for testing air, and the method of testing for ammonia by what is called Nessler's Fluid. We find the greatest quantity of ammonia, especially albuminoid, in crowded rooms and crowded streets, over middens and manure heaps; near stables, byres, and piggeries; in short, wherever animal life is abundant and a supply of fresh air deficient. Factories of various kinds, and especially chemical works, throw many impurities into the air, and there are certain kinds of works which are quite out of place in towns and cities, and should not be permitted. I need not say that this is a very delicate question in a city like our own, which owes so much of its greatness to manufacturing industry; but still an effort should be made to eliminate all those manufactures which are unavoidably and hopelessly noxious, and to conduct those that are capable of amelioration so as to produce the least possible nuisance. The Alkali Acts have done very much to put a stop to the evolution of hydrochlorine acid, sulphurous acid, and sulphuric acid from chemical works, but they are not yet sufficiently comprehensive to include all the noxious gases which deteriorate the purity of the air of manufacturing towns. Even smoke arising from the imperfect combustion of coal is a serious evil, and should not be tolerated in such a city as Glasgow, where it is by far too abundant. Our law is that a manufacturer must conduct his operations in the best possible manner, and if he does so he may deluge the atmosphere with smoke, as in the case of puddling furnaces, if he only declares in court that it is necessary. There is no power to stop a manufacture so conducted, however offensive it may be to the neighbourhood. I dare say many of you have observed how pure, comparatively, the air of London is, and there are various reasons for it; but one is that smoke from

factories is not permitted under any pretence whatever. If a manufacturer says he cannot carry on his operations without producing smoke, the authorities reply that they are very sorry, but he must do one of two things—he must find means to do away with the smoke, or he must close his work. And, strange to say, the London manufacturer always *does* find out a way of conducting his business without smoke, necessity being, in this case as in others, the mother of invention. What is wanted in Glasgow and other large towns is a law similar to that which exists in London, enabling magistrates summarily to order the closing of works which are not, or cannot be, conducted without the emission of smoke. Another serious impurity in the air of towns, and which makes it impossible that it can even be so pure as that of country places, is the sulphurous acid resulting from the burning of sulphur contained in coal—I should rather say sulphurous and sulphuric acids, and sulphate of ammonia, for they are always associated—and all the sulphurous acid is eventually converted into the more injurious form of sulphuric acid. The sulphur acids destroy vegetation, disintegrate the sandstone of our buildings, and no doubt are injurious to health, especially during calm, foggy weather in winter, when the quantity of these is often so great as to cause a sensation of choking and to nip the eyelids and other exposed parts of the face. All this acidity in the air of Glasgow is commonly ascribed to the chemical works in the north-east corner of the city, extending from Port-Dundas Road to St. Rollox, and it cannot for a moment be denied that these works assist materially in producing the effects I have mentioned; but undoubtedly the largest portion of it comes from the burning of coal. I believe I am within the truth when I say that a million tons of sulphur contained in coal are burned in Great

Britain annually, producing, as the ultimate result of the oxidation, fully three million tons of oil of vitrol, while all the chemical works in the country are said to emit only forty-five thousand tons. In addition to the more tangible impurities I have mentioned—coal-smoke and acids—the air of towns is contaminated with various gases and vapours arising from manufactures such as those of soap and candles, manures, tanning and skin-dressing, glue, starch making, brewing and malting, bleaching and dyeing, and a great many others, all of which contribute in some degree to produce the general result. Then there are in towns stables, byres, and piggeries, slaughter-houses, manure and refuse heaps, and the gases escaping from sewage either in the streets, or still worse, in our own houses. In the country we have the same influences at work contaminating the air, but there the impurities pass away at once and are diluted and oxidized rapidly and completely. The situation of a town may, and does, exert a powerful influence on its sanitary condition. If on the summit of a hill, like the towns of old feudal times, when they were so placed for facility of defence, the air may partake largely of the character of that of the country; and the same thing applies to those portions of large towns bordering upon the sea coast or upon broad rivers. In any case, the evils of town life, although incurable absolutely, are capable of amelioration. If the town is spread over a large space, with wide streets, houses of moderate height, and numerous parks, squares, and other open places, it may be, comparatively, very healthy; but if closely built up, it is impossible that it can be so. Nothing is more important in a sanitary point of view than maintaining a due proportion between the height of the houses and the breadth of the streets, as is attempted in the new building regulations,

which, I hope, will soon become law in this city. The houses in Glasgow are unusually high, at least compared with those in English towns, and consequently we should have correspondingly wide streets. An excellent rule would be to have the streets twice the width of the height of the houses, which would give streets of 80 feet to 90 feet wide; but if this cannot be attained, there should be at least 60 feet streets for three storey houses, 80 feet for four storeys, and so on. It is not only for the free passage of air that the streets should be wide—a narrow street cuts off light as well as air, and the deprivation of light is a sanitary evil only second to the want of fresh air. Our great City Improvement Scheme has done much to open up the worst parts of our city, and our railways have contributed not a little to the same end; but if we are not to have the evils we have thus uprooted repeated in our future history, we must look to these building regulations to prevent the abuses which ignorance, carelessness, and avarice may entail upon us and our children, in the shape of narrow streets, built-up lanes, hollow squares, and every available foot of ground converted into money. It is unfortunate, in a sanitary point of view, that these laws cannot be retrospective—that they cannot affect existing properties, which will therefore remain in all their deformity, unless some great improvement scheme of the future enables us to get rid of them. It will give you a good idea of the style of building in different towns, and the amount of open ground, if I tell you the number of persons to the acre of ground in a number of towns I had occasion to visit two years ago in connection with the examination of processes for the disposal of sewage. Here is the list, omitting fractions:—

	Persons to the Acre.
Halifax,	18
Oldham,	19
Coventry,	23
Bradford,	26
Salford,	26
Birmingham,	45
London,	46
Leeds,	50
Manchester,	83
Glasgow,	89

I do not for a moment presume to say that the death-rate of a town is proportional to the density of population, for many other circumstances exert an influence; but, undoubtedly, density of population is one of the chief factors in estimating the healthfulness of a town. We may safely say that the nearer the condition of a town approaches to that of the country the healthier it will be, the greater the divergence from that standard the higher will be the death-rate, and the lower the average vitality of the inhabitants. In our own city, the operations to which I have referred, and which have done so much to open up the worst of the dens of uncleanness and disease, have reduced the density of population in a very important degree; and the very marked decrease in our death-rate which has occurred during the last three or four years, is to be ascribed partly to this, and partly to the system of sanitary supervision, which, under the able supervision of Dr. Russell and Mr. M'Leod, has done incalculable good in stamping out and in limiting the ranges of infectious diseases, and which the improved condition of the city has rendered possible.

Time will not permit me to refer more particularly to the

ventilation of private apartments, workshops, and common stairs, but the general principles I have endeavoured to enunciate, as well as the dictates of common sense and the experience of everyday life, will enable you to understand that the conservation of the purity of the air we breathe, under all conditions and in all circumstances, is essential to healthful existence. I will conclude this Lecture by expressing a thought which I trust you will carry away with you—vitiated air, whether in the dwelling-house, the school, the church, or the street, is the gaseous sewage of animated life, and its removal is not less necessary than that of the more tangible form of matter which flows through our drains and sewers.

LECTURE II.

THE WATER SUPPLY OF TOWNS.

(6th December, 1878.)

LADIES AND GENTLEMEN,

Water may be regarded in three distinct lights, all of which are equally interesting and important.

I.—It may be regarded as a liquid and the type of all liquids, and as existing in three conditions—as a solid, as a liquid, and as a gas. This division of the subject is mechanical rather than chemical, and although we cannot altogether ignore it, we can only refer to it very briefly.

II.—It may be viewed as a chemical compound consisting of oxygen and hydrogen. This head, although perhaps the most interesting, will also be dismissed with a short description.

III.—It may be considered as a solvent of various bodies, both solid and gaseous, and as existing in nature in various degrees of purity. This is, to us, the most important division of the subject, and will claim the largest share of our attention.

First, then, as to the physical properties of water. A liquid is a body the particles of which have complete freedom of motion, so that its surface is always level, or, as it might be defined, at right angles to a line extending from any point of the earth's surface to the centre of gravity. It possesses

considerable weight, and is used as the standard of comparison for all liquid and solid bodies. Thus, when we say that the gravity of pig-iron is 7, of mercury 13½, and of gold 18½, we mean that these metals are 7, 13½, and 18½ times heavier than water. Again it is used as the standard of measures, for these are founded upon the space occupied by 10 pounds weight of water, which is called a gallon, a fourth part of which is a quart, an eighth a pint, and so on. Then, again, water is important as a source of mechanical power, as in ordinary water-wheels, turbine, and water engines. It is true that these engines must be placed in immediate proximity to the falls of water which are the sources of energy, thus rendering the application of this motive power limited. But we may hope to see, by-and-by, the power extended to considerable distances by means of electro-magnetic engines converting the mechanical force into its equivalent of electricity, which, in turn, after being conveyed for miles through wire, rods, or tubes, may be reconverted into mechanical force, or into heat or light. Thus, if the electric light comes into extensive use for the lighting of streets, railway stations, or large public buildings, as is likely to be the case, we could drive the magneto-electric engines by any convenient fall of water within a reasonable distance of the city, and bring the electricity by means of a metal conductor to the place where it is wanted. Not that I think it probable that this will be done in Glasgow, or in any place where coals are as cheap as they are here; for electricity is rapidly lost in passing over long distances of wire, unless the conducting surface is made very extensive as compared with what is necessary for short distances. The difficulties are great, yet not insurmountable; and if we were to use large conductors, such as 4 feet water-

pipes, and had these properly insulated, we might apply the waters of Niagara for lighting up all the towns for 50 miles round, and for driving all the machinery used within a similar radius. The weight of water that falls on the earth is something enormous. An acre of land is, comparatively speaking, a small space, and an inch of rain sometimes falls on it in two or three days: but this inch of rain distributed over the acre weighs 101 tons. Now, to bring the matter home to ourselves, the City of Glasgow (including suburbs) covers 6034 acres, and an inch of rain, which during wet weather, may fall in two or three days, will weigh 609,434 tons, while the rain-fall of a whole year (40 inches) will weigh upwards of 24 millions of tons.

Water is not less interesting in its solid form, in which it is called ice, snow, or hail—snow being merely ice in fine feathery crystals, while hail is frozen rain drops. Ice is lighter than water of the same temperature and floats upon it, the exact relation being as 1000 to 916·7—or we may put it in this way, that while a gallon of water weighs 10 lbs., a gallon of ice weighs only 9 lbs. and $\frac{1}{6}$, or rather less than 9 lbs. 3 ounces. You can readily understand from this statement that water expands in freezing, and not only so, but exerts enormous force. I have here a small iron hollow ball, which I have filled with water, and into which I have screwed an iron plug. I will place it in a freezing mixture, and in course of time the ball will be broken in two by the expansion of the water in the act of freezing. This expansion is of great use in nature in the breaking up of rocks and the pulverization of soils during frosty weather. The farmer carefully ploughs up his stubble land in autumn, and when winter comes it is ready to be acted upon by the frost, which disintegrates it in a way that could not easily be effected otherwise. Pure water

freezes at 32° of our thermometer; if salts are present, however, as in salt water, the freezing point is considerably lowered, and in freezing the salts are excluded, so that in the Arctic regions melted ice gives nearly fresh water. Not only are salts excluded, but also gases and suspended impurities. Some years ago there was a good deal of talk about the purity of the ice taken from the surface of a small loch in the vicinity of Glasgow, and I was called on to examine it. I got a block of it about 3 or 4 inches thick and about a foot square, and I found it to be so perfectly transparent that, turning it on edge, I could read a newspaper right through the 12 inches of ice. I then melted it and analyzed the water, which I found to be very pure. I afterwards, however, went to the loch and saw that the water was slightly muddy, and on analysis I found it to be very far from pure, thus showing the exclusion of both mechanical and dissolved impurities during the act of freezing.

The third condition of water is that of gas or vapour, in which it is called steam. The expansion of water in being converted into steam is very great, a cubic inch of water giving very nearly a cubic foot of steam, there being 1728 cubic inches in a cubic foot. I need scarcely remind you that it is this expansion of water into steam, together with its subsequent condensation, that is the motive power in the steam-engine. The boiling point of water at the ordinary average barometrical pressure at the sea-level is 212°, but in a steam-boiler it rises according to the pressure exerted upon its surface. Thus, if in a boiler the pressure is 30 lbs. on the square inch, the temperature of the water will be 273°. At high elevations the barometric pressure or weight of the atmosphere is sensibly diminished. For example, the city of Quito, in South America, is situated about 9600 feet

above the sea-level; the barometric pressure is about 20½ (20·65) inches, and water boils at 194°, or 18 degrees below its ordinary point. There are several inhabited places in the Andes of South America, and elsewhere, at still greater elevations, where the boiling point is yet lower, and where there must be considerable difficulty experienced in cooking food from this circumstance. At 15,000 feet (the height of Mount Blanc) the boiling point is 188°. Even the variations of barometric pressure at ordinary levels effect sensible changes in the boiling point of water. The barometer varies from 28·3 to 30·6, giving a range of 2·3 inches; and the boiling point of water varies from about 209° to 213°. I can show you in a simple way the effect of reducing the pressure, by placing under the receiver of an air-pump a glass of hot water, and removing the air, when the water will readily boil. It may be shown also by a modified experiment. I boil water in a flask with a stop-cock (and this gives me the opportunity of showing you that steam is invisible until it is condensed into water by coming in contact with the air), and when all the air is expelled I close the stop-cock. I have now only hot water and steam in the flask; if I plunge it into cold water the steam is condensed, the pressure is removed, and the water boils.

The second head under which water may be studied is as being itself a chemical compound, and undoubtedly it is one of the most interesting of all chemical combinations. It is composed of two gases, oxygen and hydrogen, the latter of which may be regarded as a gaseous metal, just as mercury is a liquid metal. Water, then, belongs to the great group of metallic oxides, of which the red oxide of iron, the mineral called hematite, is a good example. Those

of you who heard the last lecture on Air will recognise oxygen as the most active ingredient of that mixture of gases; but I have now to show you what hydrogen is, although I must be exceedingly brief.

If we present to water a metal which has a stronger affinity for oxygen than hydrogen possesses, decomposition ensues and hydrogen is liberated. The metal potassium belongs to this class, and its affinity for oxygen is so great, that when thrown into water it combines with that element so greedily that enough heat is evolved to set the hydrogen on fire; and this simple experiment shows also that hydrogen is a combustible gas. Of the more common metals zinc is one that readily combines with oxygen, although when put into water no visible action occurs. If, however, we add an acid that will dissolve off the oxide as rapidly as it is produced, hydrogen gas will be freely given off; and this is the way in which it is usually made for experimental purposes, the acid used being commonly the sulphuric, otherwise called oil of vitriol. It is an invisible gas, and when pure is perfectly inodorous and not directly poisonous, although, as made in the way I have indicated, it usually contains traces of arsenic, derived from the zinc or sulphuric acid, or both. It is the lightest of all known bodies, and was at one time used for filling balloons, but for this purpose coal gas is now universally employed. In burning, hydrogen combines again with oxygen, and water is reformed, and the flame is intensely hot, although not luminous. When oxygen is mixed with the hydrogen, and the mixture is allowed to escape through a fine orifice, the oxy-hydrogen flame is produced, which gives the greatest heat yet produced by artificial means, and is used to melt platina and other refractory metals.

and when this flame is thrown on a piece of lime or magnesia the lime-light is produced, now extensively used in theatres, especially in the Christmas pantomimes. When mixed in quantity and a light applied, a violent explosion results.

The question will naturally arise—Is water decomposable by heat? Many chemical combinations are resolved into their elements by the application of heat, the most familiar illustration I could give you being, perhaps, limestone, which, on being heated in a kiln, gives off carbonic acid gas and lime remains—the properties of which are entirely different from those of the limestone. But water is much less easily decomposed, and, in fact, it was for long a disputed point whether it could be decomposed by heat at all. This question has now been set at rest, but the experiment is one which requires much preparation, and can scarcely be shown to a large audience. It is essential to operate on a rapid current of steam, so that the separated gases may be carried off before they can recombine, and intense heat must be applied by the ignition of a platina wire by a current of voltaic electricity. The quantities of the mixed gases obtained are very minute, but sufficient to establish the fact that water is decomposable by heat. It is easily decomposed by electricity, when properly applied.

In the third place, water may be studied in its relation to other bodies, and especially as a solvent; and I have to ask your particular attention to this department of the lecture, as it includes the study of natural waters. But first let us see what pure water is. It may be obtained sufficiently pure for all ordinary purposes by distilling river or well water and then boiling the product for about 15 minutes; and its purity may be recognised by two tests—1st, when evaporated down it yields no residue, and when boiled it gives off no gas. No

water found in nature will answer these tests, for all waters upon the earth contain more or less solid matters in solution, as well as gases, and even rain-water contains the constituents of air. Pure water is perfectly tasteless, and may be said to be "flat" from the absence of the dissolved matters to which we are accustomed. It is perfectly transparent, and in ordinary circumstances is colourless, although in a stratum of 20 or 30 feet, or viewed through a tube of that length, with glass at each end, it has a slight but decided bluish tint.

Water is capable of entering energetically into combination with other bodies, the evidence of the union being the evolution of heat, as in the slaking of lime. In this case the lime combines with a third of its weight of water, forming a white powder, in which the water is no longer visible or recognisable in any way. The production of heat is well illustrated by mixing oil of vitriol with less than an equal measure of water, when the temperature rises so high that a small quantity of water, alcohol, or ether may readily be boiled in the mixture. In mere solution, as when salt or sugar is dissolved in water, no rise of temperature takes place—in fact there is commonly a sensible absorption of heat.

In nature we have distillation on a gigantic scale constantly going on. The bed of the ocean is the still or retort which contains the liquid, the sun supplies the heat required to cause the evaporation; the clouds and mountain tops give the means of condension; the earth is the receptacle into which the distillate is received. But as soon as it falls to the ground in the form of rain it begins its journey towards the great ocean, which it reaches, it may be, after hundreds of miles of travel and after many vissicitudes. We have here an endless succession of changes, a constantly revolving cycle, which will go on unremittingly as long as sun and earth endure.

Rain-water is free from the solid impurities which we find in spring and river waters, but it contains air, or rather its ingredients, oxygen and nitrogen, although not quite in the same proportions. In air we have, in round numbers, 4 of nitrogen to 1 of oxygen, but in the gases boiled off from rain water the proportions are 2 of nitrogen to 1 of oxygen. The quantity of these gases varies somewhat with the temperature and barometric pressure, but is usually from 7 to 8 cubic inches in a gallon of water. The oxygen in water plays a most important part in the economy of nature. Without it the ocean, as well as lakes and rivers, would be tenantless—no living creature could live in it. Again, air in water used for drinking is probably valuable in a dietetic point of view; at all events, it renders the liquid more palatable than it would be without it, for it is most insipid when boiled and afterwards allowed to cool. Distilled water also is very insipid, but a method is now employed for ærating it when it requires to be used on board ship, or in places on the coast of South America (Peru and Chili), where no drinking water is to be had except that distilled from sea-water. Rain-water, being very soft, is admirably adapted for washing, and in country places where it is clean it is largely used for this purpose. Sometimes it is also used for the supply of country houses, but, if so, the greatest care should be taken to avoid the use of lead in forming the gutters and in constructing the cistern, as well as in conducting it by pipes. In fact, when rain-water is used for the supply of a house, the greatest care is necessary that no lead is used in collecting, storing, or conveying the water, which acts rapidly and powerfully upon lead, and so becomes poisonous. Many cases of lead poisoning from rain-water contaminated with lead have occurred, and I recollect one which happened a good many years ago in a small town

not far from this city when nearly all the pupils in an extensive boarding-school were suddenly seized with lead cholic, arising from drinking rain-water which had been collected in a leaden cistern. Again, water collected on the roofs of houses washes all sorts of impurities into the tanks or barrels in which it is collected, and at the bottom of these it is usual to have a putrid mass of decayed leaves, which communicates a most disagreeable taste to the water, and renders it very unwholesome. In localities where only rain-water can be obtained for the supply of a house, a tank should be made underground, constructed of brick or stone, jointed with Portland cement, and covered over and provided with a pipe to admit free access of air to the interior, and above there should be a pump constructed entirely of iron, or iron and copper. The rain-water being led into this tank should be passed through a box or barrel containing coarse river sand, in order to separate all leaves and other extraneous matter—or animal charcoal may be used with even greater advantage. Water collected in this way is excellent, and may be safely used for drinking and all domestic purposes.

Rain-water is never absolutely pure, but the quantity as well as the nature of the impurity varies with the locality and the condition of the atmosphere. The only ingredients besides air, which what may be called normal rain-water contains, are traces of ammonia and nitric acid, and near the sea, and particularly in stormy weather, traces of common salt and the other ingredients of sea-water. In towns, however, and in localities where chemical and metal-smelting or calcining works abound, the rain that falls is largely contaminated with the sulphur acids, hydrochloric acid, particles of carbonaceous matter, and even traces of arsenic. The quantity of impurity depends partly on the character of the air of the town or

district, and partly on the duration of the rain—a slight shower giving rain highly saturated, while a long-continued pour gives comparatively pure water. I may say, however, that the rain that falls in Glasgow, Manchester, Newcastle, and manufacturing towns generally, is invariably acid—sufficiently so to redden blue litmus paper.

Rain-water collected away from the habitations of man and his industrial operations is the purest natural form of the liquid. It saturates the ground, particularly on the higher levels, and, percolating downwards through the soil, it forms tiny rills: these coalescing form streamlets, then rivers, gradually increasing in volume until they reach the sea. Frequently these streams or rivers expand into lakes, and these are largely taken advantage of by engineers as natural reservoirs for the supply of towns; but, in the absence of these, artificial lakes are made by damming up valleys through which streams flow. All lakes, however, are not all equally suitable for the supply of towns, even in hilly localities away from cultivated lands; for although the water is pure so far as regards contamination by sewage or products of manufacturing industry, it is frequently so loaded with vegetable matter, in fact peat, as to be unsightly in colour and disagreeable to the taste. Even the water of Loch Katrine, although collected chiefly on rocky ground, has a distinct yellowish-brown colour, which becomes very distinct when compared with a perfectly colourless spring water, or the same water run through animal charcoal. A white plate held in the Glasgow water at a depth of a foot shows a distinct yellow tint, and it is positively brown at 5 or 6 feet. The colouring power of the vegetable matter extracted from peat is very great, for in Loch Katrine water it is less than a grain in the gallon. Waters collected upon peaty ground have the

disadvantage of being irregular in composition and colour During dry, or moderately dry weather, water collects on the hill-tops and the summits of hilly ridges, and forms deep holes or depressions, called "hags," where it becomes fully saturated with vegetable matter and acquires the colour of a moderately-strong infusion of tea. When heavy rain falls this impure and highly-coloured water is washed into the streams, and thence into the lakes or reservoirs. It is right for me to say here that highly-coloured waters, although unsightly, are not necessarily unwholesome, and also that, by keeping in a reservoir or natural basin, the colour gradually becomes less, owing to the oxidation which is constantly going on. The quantity of salts in river and lake waters varies according to the nature of the drainage ground, but it is usually small, varying from 1 to 20 grains per gallon. The salts consist of carbonates and sulphates of lime, magnesia and soda, and common salt, besides traces of nitrates and nitrites of the various bases. In the case of the Scottish lakes, of which Loch Katrine is one of the most beautiful, the surrounding hills are mostly of the mica-slate formation, from which very little is dissolved out by the water which falls upon it. The total quantity of solids in Loch Katrine water, as delivered in Glasgow, is $2\frac{1}{4}$ grains per gallon, of which about $1\frac{1}{2}$ grains consist of salts, and $\frac{3}{4}$ grain of vegetable matter, $\frac{3}{4}$ grain of the saline matter being common salt. It is remarkably soft and excellent for washing and cooking, but for drinking it is rather tasteless to those accustomed to the use of harder water. It is tolerably, but not absolutely transparent, and, as I have said already, it has a light-brown colour, very distinctly seen in a white enamelled bath. My friend Dr. Mills makes an analysis occasionally of the Glasgow water, and publishes a statement of his results and conclusions. I

cannot always agree with his conclusions, since they give the impression that the water is sometimes far from good, my own experience being that it is always of excellent quality. One expression he makes use of is to my mind misleading. Speaking of the solid contents, he describes these as "total solid impurity," giving rise to the idea, which of course he does not intend to convey, that there are ingredients in the water that ought not to be there. We must distinguish carefully between the natural ingredients of water, such as the lime and magnesia compounds of which I have spoken, and the impurities introduced from sewerage, manufacturing processes, or mining operations. What we find in our water supply is no more impurity than is the salt that exists in sea-water or the oxygen or nitrogen gases that are found in rain. Pure water would neither be pleasant to drink nor wholesome; and perhaps the greatest objection to the use of water from mountain districts is that it contains so small a proportion of saline matters. No doubt a perfectly colourless water is more enticing, in a swimming bath for instance, than one containing, like the Glasgow supply, a trace of vegetable matter, but the objection is more fanciful than real. Then, again, as regards suspended matter, it is asserted, and no doubt with truth, that the Loch Katrine water is muddy and should be filtered, either on the large scale at the Mugdock Reservoir or in household filters for domestic use. I must say that I fail to see any necessity for either the one or the other, being satisfied that the quantity is not only minute but really infinitesimal. In fact, Dr. Mills has never even attempted to make an estimation of it—at least so far as I can gather from his published statements. If the average quantity be taken at $\frac{1}{100}$ of a grain per gallon, and I am satisfied that it is not more, a man would require to consume

100 gallons before he would have taken into his system one grain of this finely-divided, insoluble matter, and as that quantity would serve for more than a year, the risk to health from this cause may be regarded as mythical. But then, what if the water should contain germs of disease? I question if a filter of a purely mechanical nature, such as sand—and that is the only filtering medium that is used on the large scale for purifying water—would retain these germs, as we call them, although we know very little about them, and merely speak of them as germs for want of a more definite term. And then comes the inquiry—Where would the germs come from? Oh! there are houses on the banks of the Loch, and a hotel at one end, and a steamer plying. All quite true: but let us examine the matter a little more closely. I can speak with some authority, for I have gone round the whole Loch, and examined minutely every possible source of pollution, and I find that there is not more than one house, cottage, or hut to each square mile of water, that the hotel is something like two miles from the place where the water is drawn off, and that the steamer, which only plies for a few months in the year, rarely comes near the outflow. In respect of possibility of pollution, I hold there is probably no available source of supply more free from risk in this respect than Loch Katrine. I am glad, however, to be able to say a word of comfort to those who indulge in gloomy forebodings of evil from the cause I have spoken of, or a feeling of discomfort in drinking water from a lake, on the banks of which there are a few houses. The Corporation have made arrangements to have carried out, before next summer, a complete system of absorption and purification, which will satisfy the most fastiduous.

As regards pollution by sewage, the case is very different

when a supply is drawn from a lake or reservoir in a thickly-populated locality, or where the ground is under cultivation, or when it is taken from a river on which towns are situated. This was our own case before 1859: we drew our water supply from the Clyde after it had passed a number of towns, such as Lanark and Hamilton, and received various tributaries upon which other towns are situated, such as Airdrie and Coatbridge, not to speak of the drainage of thousands of acres of cultivated land, and of hundreds of coal and ironstone pits. Yet, I am not sure that that water was unwholesome. It was miserably deficient in quantity, and, although it went through the form of filtration, the process was carried on so rapidly that it did little good to the water, which was always perceptibly muddy, except during continued dry weather. Since then, the quantity of sewage impurities passing into the Clyde in the upper reaches of the river has largely increased, and whatever its fitness for water supply may have been in 1859, there can be no doubt as to its unsuitability now. The purifying influence of air upon water is enormous; and yet it is limited, as we find in the case of the Clyde below Glasgow, where the quantity of sewage is so overwhelming that self-purification is impossible. Yet, there are numerous instances of towns situated upon rivers where the sewage is rendered innocuous by continued contact with the air, perhaps for many miles of flow. This purification by the oxidation of the animal products is one of nature's restoratives, and is perfectly effectual under favourable circumstances; but great care is necessary, in selecting a river or lake for the water supply of a town, to avoid even the possibility of contamination.

We come now to springs and wells. When water collects upon high levels, instead of flowing off into streams, sinks deep into the ground, and, after passing through a greater or

less extent of rock or soil, appears at a lower level, it constitutes what are called springs. For example, the city of London rests upon the chalk strata, but below it is the greensand formation, which, forming a basin, crops out all round at a radius of about 20 miles. There is abundance of water in the greensand strata, and it can be had in any part of London by boring through the chalk, when the water rises a considerable height, although it does not come quite to the surface. It is this water that is used by the London brewers. There is a popular notion that London stout is made with Thames water, but it is not, and never has been, and is never likely to be, so long as water from the springs can be had in sufficient quantity. A similar formation exists in Paris, and when the chalk is bored the water rises to some height above the ground, constituting what are called Artesian Wells. In country places, generally, where there is no regular gravitation supply, wells are the only available source of potable water; rain-water, collected in barrels or otherwise, being generally used for washing, for which the well or spring-water is, from its hardness, unsuitable. These wells, when situated in towns or villages, are always more or less contaminated by drainage from cultivated and often heavily-manured gardens, from cesspools, dungsteads, stables, byres, and pigstyes. Even in single houses, and particularly in farm-steadings, the wells are in the majority of cases polluted by one or more of these sources of impurity. The wells are often little more than mere holes in the ground, roughly built with stones, and I have frequently seen them placed with the utmost ingenuity so as, if possible, to catch every available drop of drainage from stable, byre, pigstye, or midden. The deepening of wells does not necessarily give pure water, even if the surface water is carefully excluded by

puddling, for water may come from a distance and appear at the bottom as a spring, and yet the water may be impure. It is only in very bad cases that we find in wells the presence of *recent* sewage contamination, for, in percolating through the soil the animal matter is oxidized, and the nitrogen appears in the form of nitrous and nitric acids combined with lime or magnesia. Such waters may not be immediately hurtful, and are often used for many years without sensibly affecting the health; but they are at all times dangerous, and especially during the occurrence of epidemics, when they become the active means of disseminating the germs of disease. In some cases the sewage matter passes direct into the wells without undergoing oxidation, or at least without being completely oxidized, and such wells give rise to enteric fevers, and perhaps other forms of disease, even when there is no epidemic raging in the locality; in other words, the disease originates with these wells, particularly when polluted by communicating through the soil with a drain or cesspool connected with water-closets. Of all the well waters I have analysed, amounting to a good many hundreds, fully a half have been contaminated with sewage to such an extent as to render it extremely doubtful whether they should be used at all. And yet such water, unless containing fresh or recent sewage, is usually colourless, bright, cool, and fresh to the taste; and it is not, therefore, surprising that country folks, who probably have used such water all their lives, and whose systems have become habituated to the nitrates, sulphates, chlorides, and saline matters held in solution, should be unwilling to give up the use of their wells, especially when they are called upon to pay for a supply by gravitation. It is therefore necessary, in many cases, for the local authority of a village or country district to use sharp, coercive measures, and to

peremptorily close such wells as are certified to be dangerous to health.

I do not propose, in this lecture, to speak of the pollution of rivers by the sewage of towns and by manufacturing processes. So far as public health is concerned, we may accept it as an axiom that running water, however polluted by animal products, although rendered unfit for its primary uses and fatal to fish, is not likely either to generate or propagate disease, nor even to sensibly affect the general salubrity of the town or district through which the stream or river flows.

A lecture upon water supply would be incomplete without a brief description of the system of softening hard waters invented by the late Professor Clark, of Aberdeen University. The hardness of water, that is, its power of curdling soap, depends upon salts of lime and magnesia, although a large quantity of common salt, such as is found in sea-water, also curdles soap, by rendering it insoluble. The lime and magnesia may exist as sulphates or chlorides, in which case they are not affected by boiling the water, and consequently give what is called permanent hardness; but generally the greater part of the lime and magnesia, and especially the lime, exists as carbonates of these bases, and their state of solution is due to the carbonic acid gas contained in the water. I told you in a former part of the lecture that rain-water contains oxygen and nitrogen gases, but river and spring waters invariably contain carbonic acid gas also—sometimes, in the case of springs, to such an extent as to render the water sparkling, like ærated water, which is the same thing made artificially. I have here some clear lime water, and in this bottle some solution of carbonic acid gas; on the addition of a small quantity of the latter a white precipitate forms, which is carbonate of lime, but the addition of a larger quantity of the ærated water dissolves

the precipitate, and we have now a clear solution of carbonate of lime. If this is now boiled, the carbonic acid gas escapes, and the carbonate of lime precipitates out. It is this precipitate chiefly which crusts kettles and steam boilers, but always more or less mixed with magnesia and sulphate of lime, otherwise called gypsum, and, when prepared by heat, plaster of Paris. But now, if we take this hard water, and add to it just enough lime-water to combine with the carbonic acid gas, not only does all this lime go down, but the carbonate of lime, being deprived of its solvent, is also precipitated, rendering the water comparatively soft and useful for washing and all domestic purposes. In districts where only hard waters can be had—as, for instance, in the neighbourhood of London—this process is very useful, and has been carried out on a large scale with complete success.

In concluding this lecture, I must acknowledge the very imperfect treatment of the subject which the brief time at my disposal has enabled me to give, and I must ask your indulgence for many important facts which must have been omitted. In air and water we have the two great elements of cleanliness and health—where either is stinted in quantity the public health must suffer; where they abound the death-rate is lowest, the vitality highest. It has been said that cleanliness is next to godliness, but I altogether dissent from this assertion; it is not next to it, it is a part of it, and inseparable from it. The ancient Jews had an excellent understanding of the laws which govern public health, and their priests and lawgivers promulgated their views at great length in the Levitical code: our own religious teachers would do well to devote some portion of the preaching of the Word, by which Glasgow is said to flourish, to the inculcation of the first principles of the laws of sanitary science.

LECTURE III.

THE DISPOSAL OF SEWAGE.

(13th December, 1878. Councillor W. R. W. Smith in the Chair.)

LADIES AND GENTLEMEN,

I have undertaken to-night a very onerous task, namely, to endeavour to teach you something concerning the disposal of sewage. On account of the inherent difficulties of the subject, the magnitude of the interests involved, and the multifarious schemes promulgated by authorities, engineering, chemical, and agricultural, it is a subject which one might well hesitate to discuss before an assemblage of the citizens of Glasgow.

In studying the relations of the three kingdoms of nature, as they have been called—animal, vegetable, and mineral—we must start with inanimate things, earth and air. From these we derive plant life in this way: The soil supplies water and the mineral food—phosphoric acid, potash, lime, magnesia, &c.—at the same time furnishing a position which the plant occupies, without change, during its life; while the atmosphere yields the carbon and nitrogen, which, with the elements of water, produce woody fibre, starch, gum, sugar, albuminous compounds, and all the endless variety of substances which we find in the vegetable kingdom, forming at one time the

solid timber of the oak, at another the fragile creeper, twining its tendrils amongst the friendly branches; here the sombre tint of the autumn leaves, there the brilliant hues of the fairest flowers; on this side the grain, the root, and the esculent leaf, which form the staple food of animals, on that the deadly poison by which animal life may be destroyed. From plants, again, come animals, deriving all their substance from them, directly and indirectly, therefore, from the atmosphere and the soil, to which, in course of time, they must return. Thus the wheel goes round—mineral, vegetable, animal; mineral, vegetable, animal, in endless gyration—and so it will go on as long as the present order of things on this earth continues to exist.

There are three distinct products of the animal body:—First, there is the gaseous, consisting chiefly of carbonic acid gas and watery vapour, resulting from the oxidation of the respiratory food, fat, sugar, starch, and so on—and this may be called the gaseous refuse or sewage of the body; second, there is the liquid excrement or urine, and this consists essentially of water holding in solution the partially-oxidized products of the waste tissues of the body; lastly, there is the solid excrement, consisting of that portion of our food which has escaped digestion, but altered to some extent by the functions of the body. It is with the two latter alone that we have to do. They form the most important and essential portion of sewage. But there are other sources of pollution—that is, putrescible matter—besides the animal products. These consist of such things as the water poured off from boiled vegetables and meat, the washings of dishes and kitchen utensils, the water used in washing our own bodies and in washing clothes, the surface drainage of the streets, besides refuse matter of various kinds from workshops

and factories, chemical works, breweries, distilleries, and so on. It is thus a very mixed liquid, and this is one of the difficulties of disposing of it. Still, sewage is a thing we have to deal with, and such being the case, the question is how to get rid of it in the most convenient, the least injurious, and the least expensive manner.

There can be little doubt as to the original method of disposing of the animal products in what may be called the normal state of existence, when every family lived apart, surrounded by plenty of ground. Yet even in ancient times it was found necessary for the well-being of the community, as we find described in the Mosaic record, to make sanitary regulations for the proper disposal of the excreta of the camp or household. As families began to congregate into towns, the difficulties increased; and it is one of the great evils of town life that no perfect system for dealing with excreta has yet been carried out. If we examine towns where a dry system alone is in operation, as in most of the inland Continental towns, we find that there is a general unsavouriness about them, while the closets are generally odorous to a painful degree. On the other hand, the wet system has evils peculiar to itself, although, upon the whole, a water-closet town is cleaner and less offensive than the other description; yet its underground sewers generate gases, by which the soil is permeated and the houses rendered unwholesome, and the gases escape also through traps and corroded pipes into the houses. If the sewers could all be kept on the surface of the ground, with a constant run of water in them, there would be no danger from this cause, for sewage mixed with sufficient water to ensure it being kept in motion and freely exposed to the air, will never become dangerous to health, although it may be more or less offensive to the senses of sight and

smell. Perhaps the most perfect town, sanitarily, that we could imagine would be one which had in the centre of every street a copious stream of water running in a perfectly smooth channel, and with sufficient fall to prevent any lodgment of solid matter. Into this stream the sewage of every house would pass, and it might be covered over at intervals, or even throughout its whole length, with a grating so open as to give perfect access of air to the stream below, its bed being only a few inches below the level of the street. It is when excretal matter is shut up that it becomes dangerous to health. Nature has provided for its deodorization and oxidation by mixture with the porous soil and free exposure to the air; and if we defy nature, as it were, by keeping it underground, shut up from the purifying influence of atmospheric oxidation, we must be content to reap the consequences in a class of diseases which appear to be peculiarly the result of the decomposition of excremental matter under these conditions.

A great deal has been said and written about the purifying action of water, but I wish to point out to you that water *per se* has no purifying action whatever. If we were to mix excreta with pure or boiled water it would certainly dilute it, but it would not prevent its decomposition and consequent offensiveness in the slightest degree. But water in nature is never pure, it contains both mineral salts and gases, one of which is oxygen, which usually constitutes one-third of the whole. This oxygen in water undoubtedly exerts a most powerful influence on sewage, but then it requires an enormous volume to yield sufficient oxygen to render innocuous a very small quantity of sewage. A gallon of water contains, we may assume, 2½ cubic inches of oxygen gas, but the weight of this is only ·9 of a grain, while, according to my calculation,

a gallon of urine would require for its complete oxidation about 3000 grains of oxygen. It is only in extreme cases that we can have the opportunity of mixing animal products with 3000 times their bulk of water; but if we could do so, and provided there was no solid matter to settle down, there would be complete oxidation and purification. In ordinary cases we have to depend more upon contact with the air for the oxidation than the mere mixture of water, which, as I have shown you, possesses but a limited power. With respect to river pollution, the influence of sewage must be regarded with reference to quantity. For example, the drainage of a small village somewhere about Tintock would be completely swallowed up and rendered perfectly harmless before it reached Glasgow; but when we throw into the river the excrements of nearly three-quarters of a million of people, we tax the powers of air and water too severely, and the once noble river becomes at the harbour a seething puddle, a gigantic cesspool. And yet it has by no means been satisfactorily proved that the condition of the river, disgusting as it is in summer, is directly dangerous to health. The question of the conservancy of rivers is one that has for some time been engaging the attention of sanitary authorities. In the case of a number of towns, such as Birmingham, Bradford, and Leeds, the purified sewage is incomparably purer than the grossly-polluted streams into which it flows. These and many other towns are subjected to the manifest injustice of being compelled, under heavy penalties, to render their sewage clear, inodorous, and almost perfectly colourless, before discharging it into rivers or streams, which are often, as in the case of the Bradford Beck, literally common sewers of the foulest description. The inhabitants of these towns complain, and with good reason, that in the upper reaches

of the rivers wholesale pollution is permitted, while they have been put to great expense in order to accomplish a purification, the effects of which are swallowed up in the filth of other towns over which they have no control. Conservancy Boards to watch over the whole drainage area of the various river basins are the only effectual means of solving the important questions which are so intimately connected—the disposal of sewage and the restoration of the rivers to a state of purity. In the immediate vicinity of the great pumping station for London sewage, the large and important district of Stratford, itself part of the Metropolis, is left in some parts undrained, the Metropolitan Board of Works refusing to admit the sewage except at a price which the Local Board are unwilling to pay. The fact is that the sewage question is, in London, only partially solved; the Board of Works do not know how soon they may be called upon to purify their sewage before passing it into the river; and, as this will enormously increase the present outlay, they are unwilling to undertake the carriage of additional drainage at a rate which may ultimately prove insufficient. At present the sewage of London is run direct into the Thames at Barking and Crossness, without any attempt at purification. The formation of a Conservancy Board is the first step that should be taken in regard to the purification (or rather restoration to purity) of any river, and until such a Board is constituted for our own river no sewage works should be undertaken.

There are two ways in which excremental matter may be dealt with—the dry system, and carriage by water. The first is the most rational, as well as the most consistent with public health and with national prosperity. The weak part of this system is that, while it disposes of excreta, it leaves

untouched all other kinds of sewage, which still require to be removed by means of water-carriage, and demands the same purification before passing into a river as if it contained the whole excreta. While, therefore, upon economical and sanitary grounds, water-closets, especially in houses of the smaller sort, and in public works, jails, railway stations, &c., might, with advantage, be replaced by an efficient dry system, the adoption of this course would not sensibly lessen the amount of sewage to be dealt with, or render its purification less imperative.

When water-carriage is used, the following methods may be employed for the disposal of the sewage:—

1st. Running it into the sea, or into a tidal river, under conditions that will prevent its return.

2nd. Irrigation.

3rd. Purification by precipitation—

(a)—by Lime.
(b)—by Sulphate of Alumina.
(c)—by the A B C system.

The dry method includes—

1st. Pan-closets.

2nd. Earth-closets.

3rd. Goux system.

4th. Stanford's system (Carbon Fertilizer Co.)

5th. Liernur's Pneumatic system.

We shall briefly examine these various methods, chiefly in their relation to the requirements of our own city.

The system recommended by Sir John Hawkshaw for the disposal of the Glasgow sewage is to pump it up to a high level, and to carry it down to the Ayrshire coast, and then run it into the sea. Perhaps the most serious objection to the adoption of this recommendation is, that it ignores the broad principle that the people of one river basin or drainage

area should not be permitted to invade another district, in order to get rid of their own sewage, but should restore it to the river in a form sufficiently purified to prevent nuisance, and allow of the water of the river being used, to a large extent at least, for primary purposes. Apart from the enormous cost of Sir John Hawkshaw's scheme—in itself a serious obstacle to its adoption—it appears unlikely that Parliamentary sanction would be obtained in opposition to the wishes of the inhabitants of a large district with which the city of Glasgow has no connection, and to which it has no legitimate claim. The example of London in running the unpurified sewage into the Thames is scarcely one that can be followed by Glasgow. The average range of the tide in the Thames is 18 feet, while in the Clyde it is only 9 feet 9 inches; the velocity of the ebb-tide is, on the average, on the Thames 2¾ *miles*, while on the Clyde it is only 2¼ *furlongs*, or little more than one-tenth of the speed. When the sewage of London is run into the Thames at Barking and Crossness, during the first three hours of ebb-tide it passes down the river so far, before the tide flows, that it cannot return. This would not be the case in the Clyde, with its small range of tide and sluggish current; and if, therefore, the sewage of Glasgow is to be introduced into the Clyde at a distance of some miles from the city, it must first be purified either by irrigation or precipitation.

If the sewage of Glasgow were taken to Farland Point, or the Sands between Irvine and Saltcoats, the scheme would resemble that carried out by Sir J. Hawkshaw for the town of Brighton, the sewage of which is carried direct into the sea, at a place called Portobello, by a main outfall sewer, about 8 miles in length, with a fall of 3 feet per mile. Considerable difficulty was at first felt in regard to the escape of

the gases generated in this sewer and pressed backward by the returning tide, but considerable amelioration was effected by trapping off the lower part of the sewer, and ventilating the upper portion by means of a shaft or chimney, 100 feet high, with a large fire below. Ventilators have also been made in the streets for the free escape of the gases, and the condition of the town is now fairly satisfactory. A good deal has been said of the offensiveness and danger to health caused by sewage run into sea-water, in which the noxious matters decompose and are oxidized much more slowly than in fresh water; and there is no doubt that in cases where the sea is inclosed in a deep bay, and well protected from tidal currents, the evil sometimes becomes very serious. Many examples of this might be cited regarding sea-coast towns in this country, and also on the Continent, but probably a better illustration could not be adduced than the town of Campbeltown, the sanitary condition of which some time ago was very bad. In Liverpool, efficient ventilation of the sewers is obtained by iron pipes placed against the warehouses, and provided at the top with archimedean screws, and in the private houses by means of the rain-conductors. In addition to these, there are numerous openings in the streets, so that the gases pressed back by the tide are not forced, as they are in many coast towns, into the houses.

The second method of dealing with sewage is to use it in the irrigation of land, and this system has the double advantage of purifying the water in a more complete manner than can be attained by any process of chemical treatment, and of utilizing, to a certain extent, the manurial value that exists in it. Great hopes were, a few years ago, entertained that irrigation was the grand solution of the sewage question, and companies obtained from various towns concessions of the

sewage for a term of years, as if it were an article possessing an intrinsic value. All that is changed now; sewage farms, on which immense sums of money have been expended, have been reluctantly abandoned, and irrigation is no longer regarded as anything more than a means of obtaining a good effluent at a moderate outlay. Probably Croydon—a town situated about 25 miles south, or south-east, of London—has the most successful of the sewage farms, and it is no small matter to say, that it disposes of the sewage of a population of 60,000 persons, at an outlay which is now reduced to little over £1,000 per annum. But the situation of Croydon adapts it in a peculiar degree to the utilization of its sewage by filtration through land. The quantity of water used in the town per head of population is much less than in Glasgow, and the rainfall not much more than half; no pumping is required, and land is obtained in the immediate vicinity of the town. Again, the land, although not naturally of high quality, is exceedingly well adapted for sewage farming, in consequence of its being of a loose, permeable character, with a bottom of gravel, which acts as a natural drain, and prevents any accumulation of the sewage upon the surface of the ground under any circumstances. In cold or moderate weather no odours of a distinctly offensive character are given off, but in some sewage farms, during hot weather, the odour is very disagreeable, and possibly unwholesome. Mr. Hawksley, C.E., gave the following evidence before a Committee of the House of Commons in 1870 (Blackburn Corporation Improvement Bill):—"Water irrigation carried on in warm weather is exceedingly unhealthy; in fact, you make, so to speak, a kind of fen of the large area of land you put the water over." . . . "Where the water is foul [that is, not purified by precipitation] I can speak positively to it, from

repeated observation in different places, that the odour, particularly at night, and particularly upon still damp evenings in autumn, is very sickly indeed, and that in all these cases a great deal of disease prevails." . . . "With regard to sewage irrigation, this happens—The sewage forms a deposit on the surface of the ground; that deposit forms a cake of organic matter, and that organic matter, when it is in a damp state, as it usually is, gives off, in warm weather, a most odious stench."

The late Dr. Letheby, Medical Officer of Health to the City of London, also gave powerful evidence against sewage farming as affecting the health of a district. It is right to add that, at Edinburgh and several other places, no evil effects have been traced to the influence of the farms irrigated by their sewage, and that some of the most reliable authorities confidently affirm that sewage farming is not attended with injurious effects upon health.

Mr. Crookes, F.R.S., a distinguished chemist, makes the following observations on sewage farming:—"The finest manurial qualities are possessed by the constituents of sewage, but the irrigationist is so wasteful in their application that, in the majority of cases, there ensues not a healthy crop, but a mass of overgrown rank grass material of no more nutritive value than weeds; for it must be distinctly remembered that this is not a question of manuring with sewage when necessary, but the compulsory application of enormous quantities, in season and out of season, till the surfeited land is sick; and even then it has to take more still."

The quantity of land that appears to be necessary, under favourable circumstances, as at Croydon, is about an acre to each 100 of population, so that Glasgow with its immediate suburbs would require, at the present time, fully 10 square

miles of land, and, including the suburbs, nearly 12 square miles. The greater part of the sewage would require to be pumped to a considerable height, the land (supposing it were possible to obtain it) would require to be held by the Corporation; and, as experience has shown in the case of the Barking farm, large quantities of certain crops would be obtained, which it would be impossible to dispose of to advantage. Again, it is quite certain that the land occupied could never become residential, or be occupied otherwise than by the labourers engaged on the farm. This is even the case at Croydon; although, as already mentioned, the circumstances are there peculiarly favourable to sewage farming.

Purification by chemical treatment has been much misunderstood, and consequently discredited. Because it has not done all that has been claimed for it, some have been inclined to regard it as a failure, and unworthy of consideration. Several processes have been advocated for purifying sewage by precipitation, and at the same time manufacturing from the sludge obtained a manure which will be saleable at a considerable price, under the name of native guano, or some other high-sounding title. The purification of the sewage is possible, and has been carried out successfully at Bradford, Leeds, Coventry, Birmingham, and other towns; but so far as I have been able to ascertain, the sale of the so-called manure, except in insignificant quantities, appears to have failed of accomplishment. And this is not to be wondered at; for the precipitant, whatever it may be, while it removes the solid matter of the sewage, together with the phosphoric acid, leaves in the effluent water all or nearly all the ammonia, and all the potash salts, these constituting by far the most valuable part of the sewage. All hope of making anything of the precipitate or sludge should, therefore, be abandoned;

but that is no reason why the process should not be adopted for the purification of sewage.

The matters removed by lime and by alumina, which are practically the only precipitants that have hitherto been employed, are—

Solid matters,
Phosphoric acid,
Fatty acids of soap,
Nitrogenous organic matters,
Vegetable colouring matters,
Magnesia.

The soluble nitrogenous compounds and the ammonia in the effluent soon become oxidized, less rapidly in salt than in fresh water; and the oxidation is greatly facilitated by passing the purified sewage, as at Bradford, through a porous material, with free exposure to the air.

Of all the substances proposed for precipitation, the one that appears to be most capable of general application is lime. It can be had everywhere, is cheap, and effects a sufficient purification to enable the effluent to be passed into a non-potable running stream or tidal river, especially if the precipitation is supplemented by filtration through some form of charcoal, or by running it over a limited extent of suitable land, thoroughly drained, as at Coventry. It has been objected to the lime process that the effluent soon decomposes, while that from other precipitants, being neutral or faintly acid, resists putrefaction for a much longer time. This is quite true, but it appears to me that the fact that the lime effluent readily oxidizes is entirely in its favour. The organic matter in the purified sewage *must* be oxidized, and the sooner this is accomplished the less likely is it to produce injurious consequences.

Whatever method of precipitation is adopted, it is most important that the sludge should not remain long in the bottom of the settling tanks; whenever it is permitted to remain for a week or two, it ferments, throws up bubbles of the gaseous products of decomposition, and serves to render the effluent offensive—producing, in fact, the very evils so noticeable in the harbour of Glasgow, where the solid portion of the sewage of the city settles down to the bottom and undergoes putrefactive decomposition.

Precipitation by a solution of sulphate alumina mixed with the sewage, and afterwards neutralized by lime, is used at Coventry and some other towns. The special advantage gained by this process is, that the bulk of the sludge is sensibly less than that obtained by lime.

The A B C process, as it is called, has become notorious, not so much, probably, from its inherent merits, as from the pertinacity with which its claims have been advocated by the proprietors of the patent, or rather series of patents. Indeed, so much has been affirmed regarding its capabilities, that the Rivers Pollution Commissioners made it the subject of a special series of investigations, and published a Blue-book concerning it in 1870. It will be sufficient to quote the " Conclusions," page 18:—

" Our investigation into Sillar's, or the A B C process of treating sewage, as carried out at Leicester and at Leamington, extending over nearly two years, have led us to the following conclusions:—

" 1. The process removes a large proportion of the suspended impurities from sewage, but on no occasion, when we have seen it in operation, has this removal been so complete as to render the effluent sewage admissible into running water.

" 2. The A B C process removes a very small proportion of the

soluble polluting matter from sewage. After treatment by this process, the effluent sewage is very little better than that which is obtained by allowing raw sewage to settle in subsidence tanks.

"3. The manure obtained by this process has a very low market value, and cannot repay the cost of manufacture.

"4. The manipulations required for the extraction and drying of this manure are attended with a nauseous odour, especially in warm weather, and would occasion a serious nuisance if the works were situated in or near a town."

The name of the process has been taken from the initial letters of the three substances which were originally considered essential to the process—alum, blood, and clay, but other substances have been used, and the mixture has suffered a great variety of changes. The following extraordinary and ridiculous combination is stated, in the final specification, as proportions which have answered well for ordinary sewage:—

Alum, ...	600 parts.
Blood, ...	1 "
Clay, ...	1,900 "
Magnesia, ...	5 "
Manganate of Potash, ...	10 "
Burnt Clay, ...	25 "
Common Salt, ...	10 "
Animal Charcoal, ...	15 "
Vegetable Charcoal, ...	20 "
Magnesian Limestone, ...	2 "

The quantity required is stated to be about 4 lbs. per 1000 gallons of sewage, equal to about 1¾ tons per million gallons. In singular contrast to the above are the proportions most recently employed at Leeds, viz.:—

Alum, ...	... ...	3 parts.
Charcoal,	... ...	3 „
Clay, ...	... ...	6 „
Lime, ...	... ...	12 „

In this mixture the essential ingredients appear to be alum and lime, the latter being used in considerable excess, as appears from the composition of the dried sludge. As regards clay, it is a fact that the sewage of some towns contains already too much of that substance; and what is added only increases the bulk and weight of the sludge, without offering any compensating advantage. One object of the addition of clay is to ensure rapid precipitation; but this appears to be equally well attained by the use of lime alone.

Whatever system of precipitation be adopted, the disposal of the sludge is one of the most important elements in the calculation of cost. It is estimated that the sewage of Glasgow—40 to 70 millions of gallons daily—will produce a quantity of sludge which, in the dried state, would amount daily to 135 tons; but as it must be dealt with in its moist condition, it would be a fair estimate to take five times this, or 675 tons, as the quantity to be daily got rid of. Probably it might be used to some extent for filling up waste and low-lying land on the banks of the river; but, if not required for this purpose, it might be carried down to Loch Long, and deposited in the same way as the dredgings of the river are disposed of at the present time. If the sewage of Glasgow were conveyed 7 or 8 miles down the river, and there purified by precipitation, the sludge could be disposed of by hopper barges, at a cost of 6d. per ton—equal to £16 17s. 6d. per day, or £6160 per annum. If lime alone were used as the precipitant, 40 tons would be required daily, which,

at 12s. per ton, would cost £24 a day, or £8760 per annum. The total cost of working the precipitation process, not including interest on works, would probably amount to about £25,000 per annum.

I can only refer, in passing, to intermittent filtration as a means of purifying sewage. It has been carried out quite successfully at Merthyr Tydvil; but the conditions are there so exceptional, that there are very few places where the process could be pursued with equally satisfactory results. It appears to be in operation also at Kendal.

Before leaving the subject of water-carriage I must allude, however briefly, to the defects of the system. The purification of our river, however desirable on æsthetic grounds, would do little or nothing for the diminution of our death-rate or the salubrity of our homes. It will not prevent the formation of sewer gases, or the passage of these pestilential effluviæ into our dwellings; on the contrary, unless special precautions are taken, it will, from the connection of the sewers with the intercepting main drain, increase the danger by lessening the very imperfect ventilation of the sewers which at present exists. If a scheme of purification be carried out, either by conveying the sewage direct to the sea, or by defacating it, and then returning it to the river, it will become more than ever necessary to adopt a thorough system of ventilating the sewers and drains. As regards the street sewers, the simplest method is to have openings in the *middle* of the streets at short distances, covered with gratings of such a form that they will not be readily stopped up with mud. These should be placed in every street, and at such short intervals that not only would the gases escape freely, but a considerable amount of æration would also be effected. Then, again, as regards water-closets, it should be made compulsory to have

in each closet a ventilating pipe to convey away the gases from the trap to the exterior air, and the supply of water for household purposes from the cisterns connected with the closets should be absolutely forbidden. It has been suggested that a tax should be placed upon water-closets, so as to discourage the use of these as much as possible, especially in houses of the smaller class, where they are more likely to get out of order, and to prove injurious to health, than in houses of the better description. A tax of 10s. per annum on each closet would produce an income of £16,000, which might be applied in the payment of the necessary inspection, and in diminishing the rate for sewage. Set-in basins in bedrooms are equally in need of inspection. For the ventilation of the great main sewers, it has been proposed to make use of the chimney stalks connected with the various public works throughout the city, or to erect "destructors," as they are called, to consume the refuse of the city, and at the same time produce a powerful draught. This would at least prevent the escape of gases into the streets, and assist in ærating the sewage, as there would be a current of air down the street gratings. The gratings at the *sides* of the streets should be trapped, in order to prevent the gases from escaping at the place frequented by foot passengers.

As regards chemical and other factories, from which enormous quantities of refuse matters are emitted, manufacturers should be prohibited from putting into the sewers any liquid having an acid reaction, as such liquids (pot-ale from distilleries, for example) decompose certain compounds in the sewage, and liberate noxious gases. As lime is cheap, there would be no hardship in carrying out this regulation. All solid matters of whatever kind should also be kept out of the sewers.

is still better, in so far that the weight of charcoal is small as compared with that of the quantity of earth required to effect a similar amount of absorption. But these closets, although admirably suited for country houses of the better class, are too expensive in themselves, too costly to work, and to delicate in construction, to be used for ordinary workmen's houses in a crowded town or city. The charcoal system has been introduced on the large scale at Oldham by the Carbon Fertilizer Co., but the way in which the work is carried on is not altogether satisfactory.

A lecture on the disposal of sewage would be incomplete without a reference to the pneumatic system of Captain Liernur. A detailed description would occupy too much time, but I may refer you to an excellent popular description of it published in *Good Words* for November, 1876. Details of the system, as carried out at Dordrecht, Leyden, Amsterdam, Vienna, and other continental towns and cities, are given in the Report on the Conference on the Health and Sewage of Towns, held at the Society of Arts, London, May, 1876. The distinctive feature of the process is that the night-soil, with or without a limited quantity of water, is drawn by means of a vacuum to a central depôt, where it is evaporated to dryness in vacuo, forming a "pondrette," which possesses a high manurial value, and may truthfully be called native guano, a name which has been applied by the A B C Company to the same article—*minus* its ammonia and alkaline salts, and *plus* a large quantity of clay and other useless material. While the pneumatic method of disposing of the excreta is the central idea of the system, it includes also distinct operations for dealing with kitchen-sink refuse and street washings. I cannot express an opinion upon the working merits of the system, but may say that, theoretically,

and in an economic point of view, it appears to be perfect, since the whole of the excreta is converted into a portable and valuable manure, while all risk of sewer gases being formed is obviated, and all the operations, being conducted in vacuo, are free from offence.

The following remarks on the pneumatic system is quoted from the Report to the Local Government Board, by Messrs. Rawlinson and C. S. Read, dated 21st July, 1876, but it refers to the use of the actual manure without evaporation:—

"Captain Liernur has been particularly fortunate in having the manure which his system produces tried in Holland, as the use, application, and storage of liquid manure is much better understood there than in England. A considerable number of the farmers in Holland grow no straw, consequently the manure made by the cattle in winter has to be utilized in a liquid state. In England this liquid manure is generally absorbed by the straw, or by other bedding upon which the cattle stand. Some twenty years ago there was a general movement amongst English farmers for applying the drainage from farm yards to the land, and tanks, pumps, and liquid manure carts were, for a time, in great request; but the application of this farm sewage produced so little result in proportion to the cost, that pumps and carts for this purpose are now seldom used upon arable farms. We are confident that the liquid which is collected at such cost in barrels would find no ready sale in England, even at a very low price, and we further believe that any English farmer agreeing to take it continuously would not only not pay anything for it, but would certainly charge something considerable for his trouble and for the expense of removal.

"If the towns of Holland, or portions of such towns, by reason of peculiarities of site and climate, cannot be sewered

on English principles, and if the pneumatic system is as cheap as any of the moveable pail systems, it may be best under such conditions for Holland, because, if worked in accordance with the rules laid down, the excreta will be removed daily without the intervention, trouble, and dirt involved in the pail system. The pneumatic system only deals, however, with a small fraction of the refuse to be removed from houses, leaving all other forms of refuse to be dealt with in the ordinary way; so that Dutch town sewage must flow into the rivers and canals, as now, to pollute the water supply; or some complicated mode of intercepting it must be provided at an additional cost to the local authorities.

"The pneumatic system is ingenious, but it is complicated in its construction and working arrangements; and consequently it is liable to derangements which are sometimes difficult to mend. We do not know one English town in which the apparatus, if adopted, would be other than a costly toy.

"As may be imagined, when the nature of the arrangements and complications are considered, the pneumatic system gets out of order, the slightest crack in any pipe or pipe-joint will reduce the force of the partial vacuum, and even when all the apparatus remains sound, the closet pans may not be emptied; and, in fact, neither the pipes nor the pans ever are entirely emptied."

The following recommendations regarding the disposal of the sewage of Glasgow are given in the Report by the Deputation to which I have referred, and from which I have quoted very freely in this lecture:—

1. That the system of having water-closets for public works, factories, jails, workhouses, infirmaries, and railway stations,

should be forbidden, so as to reduce the quantity of water-closet sewage now turned into the river. Water-closets in small houses should also be discouraged.

2. That the ordinary privies and ash-pits be altered to the tub and pail system, to be cleansed daily, as it has been carried out in Manchester and other important English cities and towns;* and that special accommodation be provided for children.

3. That all drains, soil and waste pipes, and all apparatus connected with water-closets, sinks, and baths, and their connections, be executed under public supervision.

4. That a complete system of ventilation of the common sewers throughout their entire length be immediately adopted.

5. That a system of ventilation of the house drains and soil-pipes, independent of that of the common sewers, be immediately adopted and enforced throughout the city.

6. That the use, for dietetic purposes, of water from cisterns supplying water-closets should be absolutely forbidden.

7. That, in the event of it being found necessary to purify the river, the whole drainage of the city be taken into main intercepting sewers, and conducted to a suitable point, and, after being rendered clear by precipitation and filtration, passed into the Clyde.

8. That the sludge obtained in the precipitation process be got rid of in the cheapest possible manner. A part of it might be utilized in making up waste land, and a certain quantity might be taken away by farmers; but the greater part would probably require to be disposed of in the same manner as the dredgings of the river.

It will thus be seen that the idea of utilization of the sewage itself, or the precipitate obtained by the action of lime or other chemical agents, is entirely discarded. The sludge obtained by any of the patented processes is dried at

* This recommendation has already been carried out.

such cost, and its value when dry is so trifling, that all hopes of disposing of it for manurial purposes—at a price that would be remunerative—are entirely illusory.

It is scarcely within my province to form estimates for the construction of the works, or the working of the precipitation process, and the following figures represent merely my own idea of what the probable outlay may be, basing the calculations upon the cost of similar works erected in other places, and the estimates in Sir John Hawkshaw's Report:—

Intercepting sewers—two on the north side, one on the south; total length about 28 miles, ... say	£500,000
Two pumping stations, ...	100,000
Cost of precipitation works, north and south,	130,000
Contingencies and interest of money during construction, ...	120,000
Total, ...	£850,000
The interest on this sum at 4°/₀ is	34,000
Cost of pumping and precipitation per annum, and disposal of sludge, ... say	31,000
Total annual cost, ...	£65,000

Equal to a rate of about 6½d. per pound of rental. A portion of this amount would, if the arrangements referred to were carried out, be borne by the suburban burghs. If it were preferred to extinguish in 30 years the debt incurred in the construction of the main conduits and precipitation works, the interest would be 6 per cent., making the total annual charge £82,000, or about 8d. per pound of rental.

If a separate system of sewers were adopted for the house drainage, and the sewage reduced to a regular quantity of about 30 million gallons per day, the cost of working, both

as regards pumping and precipitation, would be considerably reduced, and the quantity of sludge would also be much lessened. The intercepting and main sewers would also be only of half the carrying capacity, and the cost of their construction would be much less than if the entire drainage of the city were collected for purification. On the other hand, the construction of a second set of sewers would be attended with a large outlay of money, and the purification of the river would be less complete.

In conclusion, it may be useful for me to make mention of a few statistics of the condition of Glasgow with reference to the question of sewage, which I take from the Appendix to the Report by a Deputation of the Town Council, published about a year since, page 45.

GLASGOW.—The following statistics relating to our own city will be useful for comparison:—The estimated population in 1875 was 534,564, and the average mortality (1871-5) was 29·9. The area of ground occupied is 6034 acres, giving an average density of 88·6 persons to the acre. The number of dwelling-houses in 1874 was 101,368, and of shops, warehouses, and factories, 16,218; the water-closets numbered 31,927; sinks, 71,291; fixed basins, 3865; and urinals, 211. There are also, at the present date, 6751 dry ashpits, 1395 middens or wet ashpits, 3816 pan closets, 94 trough closets, chiefly in public works, and 13 public conveniences, 7 of which are fitted with pans, and 6 with Macfarlane's patent troughs. 109 manufactories discharge refuse of various kinds into the sewers; and there are 2304 stables with 7024 horses, and 311 cow-houses with 1350 cows. In addition to the factories, the refuse of which is conveyed into the drains, 20 discharge direct into the river. The length of the sewers is about 100 miles. Within the city boundary there are at present 131½ miles of paved streets, 20½ miles of statute labour roads, and 10 miles of turnpike roads—in all, 162 miles.

The estimated volume of the whole discharge into the river daily is 40 millions of gallons, exclusive of rain-fall, but including the

water of the Molendinar and other burns. The average rain-fall (40 inches in the year), if there were no evaporation from the ground, would be nearly 15 million gallons per day, giving a total average of 55 million gallons per day. The volume of the River Clyde at Glasgow, in ordinary circumstances, was estimated by Mr. Ure, C.E., formerly engineer to the Clyde Navigation, at 48,000 cubic feet per minute, which is equal to 432 million gallons per day; so that the sewage and drainage of Glasgow adds, at most, about one-eighth to the volume of the river. In very wet weather the flow of the river must be something like ten times the above quantity. Sir John Hawkshaw makes provision for a fall of one-quarter of an inch of rain in twenty-four hours during wet weather, any quantity above this being considered storm-water to be carried of by special sewers into the Clyde. A quarter of an inch of water upon a surface of 6034 acres is equal to 152,358 tons, or in round numbers, 34 million gallons. The total quantity of sewage in wet weather would therefore be about 74 million gallons per day, and in dry weather 40 million gallons. If a separate system of drains for sewage were adopted, the rain-fall and manufacturing refuse being carried direct into the river, the quantity would be about 30 million gallons per day, with very little variation throughout the year.

Mr. J. M. Gale, C.E., engineer of the Corporation Water-works, states that during 1876 the quantity of water sent into the city and suburban villages averaged 33 millions of gallons per day. It was distributed to a population of 710,000, so that the volume of water per head was 46½ gallons per day, being a reduction of about 6 gallons as compared with the previous year. It is estimated that 14 gallons are used in manufactures and for general trade purposes, leaving for the actual domestic consumpt 32½ gallons per head. Mr. Gale estimates that by further improvements in the distributing plant and house fittings the figure may ultimately be reduced to 20 or 25 gallons. The population supplied by the Glasgow Water-works has doubled since 1833, and if a similar rate of increase continues, we shall require 55 to 60 million gallons per day by the end of the century.

According to Sir John Hawkshaw, the area draining into the Clyde above Gourock is 1481 square miles. The tidal portion of the river receives four principal tributaries—the Leven, Black Cart,

White Cart, and Kelvin. The area drained by these tributaries is 632 square miles, and the population of the towns and villages situated upon them was, in 1871, 128,000. The population of Glasgow, including the suburbs of Partick, Hillhead, Springburn, Govan, Kinning Park, Crosshill, Pollokshields, Strathbungo, Mount Florida, Crossmyloof, Shawlands, and Rutherglen, was, in 1871, 569,000. The population of the towns and villages on the Clyde below Glasgow, including Renfrew, Duntocher and Faifly, Old Kilpatrick, Helensburgh, Port-Glasgow, Greenock, and Gourock, was, at the same date, 87,600; and on the Clyde above Glasgow, including Lanark, Hamilton, &c., 34,400. The tributaries above Glasgow are the Rotten Calder, North Calder, South Calder, Cadzow, Douglas, Nethan, and Elvan, and these have towns and villages upon them having an aggregate population of 90,000. The total population in 1871 was 909,000, and it may now be safely assumed to be, in round numbers, 1,000,000.

Mr. Gale, in his fourth Quarterly Report for 1877, makes the following remarks:—

"As an evidence of the extent to which all modern conveniences are being introduced into dwelling-houses, I may mention that, during the past year, 7486 water-closets and 393 urinals have been put up in new houses. In 1864 an enumeration of the water-closets within the area of supply was made, when the number was found to be 28,054. Since that time the increase has been very great, and the number of these appliances must now approach 100,000."

It will be observed that these statements refer, not to the Municipality of Glasgow, but to the whole area of water supply, the estimated population of which, in April, 1877, according to the books of the Water Trust, was 730,000. The statistics show very clearly how much the suburban population is adding, year by year, to the pollution of the river.

LECTURE IV.

FOOD AND ITS PRESERVATION.

(20th December, 1878. Councillor Smith in the Chair.)

In studying the chemistry of food, it will be well to start with an example of what may be called a perfect food—one which is of itself able to support life—and we find it in milk, which is the type of food of every kind. It is obvious that the natural food of the young mammalian animal of every species is the milk of its mother, and hence milk may justly be regarded as a model food for the species to which the animal belongs.

Milk is a thin, mobile liquid, but white and opaque; hence all liquids having a similar appearance are described as being milky. It has a slight, but not disagreeable odour, varying with the animal by which it has been secreted, and likewise with the description of food upon which the animal has been fed. It has a bland and slightly sweet taste. It is the only variety of food that will serve alone for the nutriment of animals, containing in itself all that is required for the formation of blood, and from it flesh, skin, bone, and fat, as well as respiratory food to support the heat of the body, and water, with which to form blood and the various secretions.

The ingredients of milk are, besides about 87 per cent. of water, a nitrogenous or flesh-forming constituent called casein, because it is the essential component of cheese, fat or butter, sugar of milk, which is not so sweet as cane sugar, and salts or mineral matter.

Let us examine briefly the varieties of food of which I have spoken, and, first, as to respiratory food, by which I mean those substances by the combustion of which the heat of the body is supported. All these consist of compounds of carbon with hydrogen and oxygen, and include fats and oils of every kind, both animal and vegetable, sugar, gum, and starch; the latter forming a group in which the hydrogen and oxygen are present in the proportions to form water, and have therefore been called the water-carbon series. When any member of the series is treated with oil of vitriol, especially if warm, it is decomposed, the oxygen and hydrogen, combining, form water, which unites with the sulphuric acid, while the carbon is set free—a striking experiment when made with pure white sugar. In fats, such as butter, the proportion of oxygen is comparatively small, and the heat produced by burning or oxidation is much greater than in the case of sugar or starch, although both of these bodies burn with great avidity, as I will show you by applying heat to a piece of loaf-sugar. It first melts, then blackens and gives off gases, at the same time burning somewhat fiercely. Now, note this—that fat, sugar, gum, starch, cannot by any possibility produce blood or afford nourishment to the body. True, they may, if taken in conjunction with flesh-forming substances, store up fat, and every animal has a certain amount of fat laid up as a reserve, upon which it may fall back in case of deprivation of food or disease—but this is all. The flesh-formers or blood-producers are an entirely separate class of chemical compounds. There

are a number of them differing in their properties, but only very slightly in composition—(1) We have the fibrin of flesh, (2) the albumen of eggs, and (3) the casein of milk—all these belonging to the animal kingdom; while in plants we have a similar series—vegetable fibrin, vegetable albumen, and vegetable casein, the properties and composition of which resemble very closely indeed the corresponding products of animal life. All these bodies contain, in addition to carbon, hydrogen, and oxygen, the element nitrogen, and hence are often, to distinguish them from the water-carbon and fat series, called nitrogenous or azotized principles. A simple experiment will serve to distinguish between the two classes. If we take some cotton or starch, or pieces of wood, which represent the respiratory series, and distil them by heat, we obtain a product which is acid, and contains, as an essential ingredient, acetic acid or vinegar. The odour is pungent and sour, and at the same time tarry. Now take a nitrogenous or flesh-forming compound, and treat it in the same way, and there is obtained not an acid, but the volatile alkali—ammonia—which may readily be recognized by its odour and its alkaline reaction upon vegetable colouring matters. We may take for this purpose pieces of feather, silk, wool, hair, down, or dried flesh or white of egg—the products are the same in each case.

It is singular that, so far as the fabrication of chemical compounds is concerned, the powers of plants greatly exceed those of animals. We put a seed in the ground, and soon it springs into life and forms a plant, and that plant takes from the air the carbon, hydrogen, nitrogen, and oxygen, and from the soil the mineral matters, out of which it forms all the substances, nitrogenous and non-nitrogenous, which have been already mentioned. But animals have no such power; give them air,

water, and earth, and they will never form a single microscopic cell of any organic body. They are entirely dependent on plants for the supply of all their wants. And not only this, but their powers of changing organic compounds are exceedingly limited, for all the nitrogenous constituents of our bodies exist ready-formed in the vegetable world. We may change their physical characters in some degree, but their composition remains, to all intents and purposes, the same. Even those animals that prey upon others obtain their supply indirectly from plants. We cannot eat grass, but we employ sheep and cows and oxen to do it for us; and we drink the milk of the cow, and eat cheese and butter made from it; and we eat the flesh of the sheep and the ox, and we give hens corn or other vegetable food, and eat their eggs; and so we are, in a sense, vegetarians after all.

As regards the mineral constituents, these are not less essential to the animal economy than the other ingredients. The bones, which form the framework of our bodies, consist essentially of phosphate of lime, with a certain proportion of a substance allied to gelatine, and in our blood there are various salts, without which we could no more continue to live than we could without the organic portion of our food. In milk, the proportion of mineral matter is particularly large, forming about 5 per cent. of the total weight of the solids; and I think this should teach us to avoid descriptions of food which contain only minute quantities of mineral constituents, such as bread made from very fine flour.

With the various ingredients of milk you are tolerably familiar. The fat we find in a nearly pure state, except as regards a little water mechanically held in it, in fresh butter; while salt butter is the same, with from 5 to 10 per cent. of salt mixed up with it, in order to make it keep. There is

another way of preserving butter, which is well suited for long voyages. The butter is melted at a very moderate heat, when water and curd settle down, and the real butter floats on the top as a clear, yellow oil. This is drawn off into perfectly dry and clean bottles, and, while warm, corked up tightly, and it will keep perfectly fresh and sweet for a long time.

The curd is separated from milk by adding an acid—almost any acid will do—when the trace of alkali, which milk naturally contains, is neutralized, and the casein falls as a curd, carrying with it, at the same time, the fat or butter which is held mechanically in the liquid in minute globules. On the large scale, instead of adding an acid, a ferment called rennet is added to the slightly warm milk, which acts upon the sugar, converting a minute proportion of it into lactic acid which combines with the soda, and separates the casein or curd, which, when slightly salted and pressed, constitutes cheese.

Cheese consists of various proportions of casein and butter, according as it is made from sweet milk, skimmed milk, or a mixture of sweet milk and cream, which gives exceedingly rich cheese. There is always, also, a considerable proportion of the salts originally held by the milk, also a certain amount of water. I may give you two examples of cheese, one a rather rich variety, the other poor—

	Cheddar.	Skim Milk.
Curds or Casein, - - - -	29	45
Fat or Butter, - - - - -	31	6
Ash or Salts, - - - - -	4	5
Water, - - - - - -	36	44
	100	100

Cheese, moderately rich, such as Cheddar and Cheshire, as well as the common Dunlop cheese, made extensively in Ayr-

shire, is more wholesome as an article of diet than excessively rich or very poor varieties, such as cream cheese or Stilton on the one hand, or skim milk on the other. Cheese is most digestible and most useful as an aid to digestion, when old and mouldy.

When the curd is separated in cheese-making a fluid collects above, called whey. It is slightly sweet, and contains sugar—not cane-sugar, however, but a peculiar variety called lactose or sugar-of-milk. It is not nearly so sweet to the taste as cane-sugar, and is less soluble in water.

Preserved milk, sold in tins, and very useful for excursions, yachting, and sea voyages, is made by evaporating down milk in vacuum pans at a very low temperature, and adding an extra quantity of sugar. It is an excellent substitute for fresh milk.

Milk is extensively employed to confer greater nutritive power upon various farinacious substances, such as arrowroot, corn-flour, tapioca, and sago. These dietary articles are simply varieties of starch, and are practically vehicles for converting milk into a solid and convenient form. Of course, starch is an important respiratory food, but has no nutritive power. Other articles used in a similar manner contain certain proportions of nutritive principles, and are in this respect superior to the starches; such as rice, hominy, or the interior portion of the Indian corn seed (much used in America), pearlina, made in a similar manner from wheat, and macaroni, also a preparation of wheat.

The ease with which milk may be adulterated makes it more subject to sophistication than any other article of food. The most common means of earning an extra profit is the addition of water, which may be considered moderate if it does not exceed 10 per cent., and excessive if more than

20 per cent. The addition of water, although a gross fraud, is not so bad, however, as another form of adulteration which I cannot find words too strongly to reprobate—I mean the addition of old or skim milk to new milk. This mixture, especially if the new milk is warm, rapidly becomes sour, or "turned," as it is called, and in this condition is very unwholesome, especially to young children. This fraud is not so easily detected as the other, and requires the skill of the practised analyst, but when clearly proved should be punished with the highest penalty that the law permits. It is not for mere taste or comfort that I hold extreme views in regard to this form of adulteration—the very lives of infants are not unfrequently sacrificed to the greed of the dairyman.

Cream comes to the surface when milk is allowed to stand for a few hours. In twenty-four hours good milk should give at least ten per cent. of cream; but the amount is rather variable, according to the season of the year, the breed of the cow, its age, and other circumstances; but it is rarely less than eight per cent. in genuine milk, or more than fourteen per cent. The cream when skimmed off without taking any of the milk, is very thick, slightly lighter than water, and contains from thirty-five to forty per cent. of fat, but in practice the milk is skimmed with a cup, and the cup is put well down into the milk, and the result is that we may be considered very well off if we get one-third cream and two-thirds milk. This would give twelve to thirteen per cent. of fat, and that is considered very good—in some cases it goes much lower. At present there is no recognized legal standard for cream, but it is highly desirable that a standard should be fixed.

I propose now to direct your attention to another type

of food, namely bread—an article of such importance that it has aptly been designated as the "staff of life." Wheat is a grain with which you are, no doubt, all familiar. It consists essentially of two parts, the interior white, soft portion, and the integumentary coating or husk. In consequence of the comparative hardness and toughness of the outer portion, the process of grinding, to which the grain is subjected, by the miller, reduces it to a flour, easily separated by bolting or sifting into fine flour of a white colour and in a state of fine division, and a dark scaly-looking substance, called bran. There are also various intermediate qualities, separated by sieves having different sized meshes. It is the aim of the miller to separate the bran and intermediate qualities as completely as possible from the flour, in order that the latter may be as white as possible; although I shall show you, by-and-by, that this complete separation of the coarser particles is not, in a dietetic point of view, so desirable is it appears to be.

When flour is mixed with water it forms a stiff, tenacious mass, called dough; and this, when baked, forms either a hard biscuit or a close, heavy, rather damp, substance, called unleavened bread. This name is now improperly applied to any kind of bread raised by any other means than fermentation, and which bread may be as well raised as the ordinary variety. The original unleavened bread, as used by the Jews, was not raised at all, and was in fact the same as the tough and eminently indigestible article known to colonists by the name of "damper." In order to make bread, something must be added to the dough to separate it into little spaces—in other words, to communicate to it a cellular structure. Flour contains a small quantity of sugar, and this, by the action of a ferment called yeast,

barm, or leaven, is decomposed and transformed into alcohol and carbonic acid gas; just as the same compounds are formed by fermentation in the brewer's vat. Yeast is a plant of the very lowest order, consisting of microscopic cells, which, however, are sometimes grouped together in strings, as represented in the rough sketch I have prepared. The making of bread is sufficiently simple, but requires considerable nicety of manipulation and a considerable amount of manual labour. In commencing to prepare the dough a quantity of water is taken, which in winter should be slightly warm, and to this the yeast is added, and then one-fourth of the flour. The quantity of water which flour requires to make a suitable dough varies with its quality —as a rule the finer and whiter it is the larger the proportion of water it will take up. After resting some time, a proper quantity of salt is added, and the mass, technically called "the sponge," is placed in a trough in a warm situation. Fermentation soon sets in, the sponge becoming distended to double its original dimensions, when it generally bursts, a large quantity of gas escaping. After collapsing, it soon rises again, and sometimes the baker allows it to burst a second time; but if the fermentation is allowed to proceed too far, there is danger of souring. The remainder of the flour, with a due proportion of water and salt, is now added, and the laborious operation of kneading goes on until the fermenting sponge is thoroughly incorporated with the materials added. Without this precaution the cellular texture of the bread would not be obtained, and the fresh flour would be left throughout the mass in doughy fragments. By the mechanical treatment to which it is thus necessarily subjected, the glutinous parts of the flour are rendered so elastic that the dough is capable of being

expanded to twice or three times its volume without danger of cracking. The kneading is performed in long wooden troughs, and worked up with the hands; but in large baking factories a doughing machine driven by steam-power is frequently employed.

The trough is now covered up, and left at rest for a few hours, during which active fermentation occurs, and the dough "rises," after which there is a second kneading, for the purpose of breaking up and distributing the gas bubbles equally through the mass. The dough is now weighed out into pieces for 4 lb. or 2 lb. loaves, an additional weight being added to compensate for the loss that occurs in firing and in standing for 24 hours, as a loaf should be full weight the day after it is baked. In the oven the fermentation is soon arrested, but the gas already contained in the dough is so much dilated by the heat, that when the loaves are removed from the oven they are twice as large as the dough when put in. Those loaves that are to be crusted all over are placed separately in the oven, and generally rubbed over with a little lard to prevent the crust from becoming hard and thick; but common loaves are put close together, in such manner that only the top becomes crusted, and this is usually brushed over with sugar or treacle and water, to give it a rich brown colour, while the under side next the sole of the oven is dusted with flour, and forms the white crust. The only materials used in making bread are flour, water, yeast and salt—5 lbs. of the latter being used to a sack of flour, weighing 280 lbs. This quantity of flour makes 90 4 lb. loaves, or 180 of 2 lbs. Some baking establishments are extensive—I know of one in Glasgow which uses 700 sacks of flour every week, out of which is made 252,000 lbs. of bread.

Bread prepared as I have stated consists of an aggregation of cellular spaces united by an integument, and, if the kneading has been properly performed, the cells or spaces are arranged in a succession of layers one above the other and at right angles to the crust. When new it is soft, but not actually damp; after keeping for a day it is firmer and more crumbly; if kept still longer in a tolerably dry atmosphere it becomes hard, and shrinks considerably in bulk. It should be kept in glazed earthenware vessels, with close fitting lids, where it will retain its properties for several days without becoming over stale. New bread is very difficult of digestion, and its use should be avoided. Stale bread may be restored to the condition of new bread by placing it in a close tin, and firing it in an oven for a short time.

Bread, in various forms, may be raised by carbonic acid set free from a mixture of bicarbonate of soda and tartaric acid, which is the essential composition of all the baking powders sold by druggists and others; although it is common, in order to cheapen it, to add rice-flour, or some farinaceous substance. For home use, bicarbonate of soda with buttermilk is often used. The best acid to use with the carbonate of soda is the hydrochloric, for by the combination common salt is produced; but that acid requires more care than can generally be given. Sweet cakes are raised by carbonate of ammonia, which, after accomplishing this object, is entirely volatilized by the heat of the oven; also by eggs frothed up. There is a system of raising bread which is the invention of Dr. Dauglish, in which carbonic acid is generated in a separate vessel, and forced into the dough by suitable machinery. This bread is very sweet and pleasant to the taste, but owing to the difficulties attending the manufacture, its use does not

appear to be extending. In the fermentation there is some risk of souring, and it was long ago recommended by the late Professor Liebig that lime-water should be used for making up the dough, instead of ordinary water, and the system was introduced into Glasgow with decided success, the bread being remarkably sweet, besides being very wholesome; but the trouble of mixing lime with water, and allowing the excess to settle down proved too much for the bakers, and the process was abandoned.

Let us now look to the constituents of flour and bread. If we mix flour with water, we make dough; and if we knead up the dough in a vessel of water, the water soon becomes milky, and if we go on for some time, nothing is left in the hand but a glutinous, sticky substance, which consists almost entirely of vegetable fibrine, the same substance *chemically* as the fibre of lean beef. If now we allow the milky water to stand for some hours, it will become clear, and at the bottom of the vessel a white substance will have collected, which is common starch, of which the flour contains about $\frac{7}{10}$ of its weight. Starch is actually made in this way in Italy, and the gluten that is left is mixed with a further portion of flour into a proper consistence, and then passed through some kind of mandril, by which it is made into pipes, or sticks, or threads, constituting maccaroni and vermicelli, which are exceedingly nutritious, and a delightful article of diet when simply boiled with milk, and not spoiled, as it usually is in this country, by being cooked with cheese. The chemical test for starch is a solution of iodine, and if we add some of that liquid to the water in which the flour was kneaded, it will become blue, from the formation of iodide of starch. The proportion of gluten in flour is usually about 10 per cent., but it varies slightly, certain kinds of wheat giving flour with only 7 per

cent. of gluten, while others go as high as 12 per cent. Of course, the more gluten the flour contains, the greater is its nutritive value.

Next we come to the oil, but I cannot show you its extraction in a lecture experiment. It has to be dissolved out by ether, or some other solvent, and the solution has to be evaporated, when the oil is left. It is yellow, and without any distinctive properties, perhaps resembling almond oil more closely than any other of the common oils. The proportion of this constituent varies from 1 to 1½ per cent., being least in very fine flours, and highest in the coarsest kinds, which are also the most wholesome. Our own oatmeal is pre-eminent in this respect, for, besides being more nutritious than flour, it contains a very much larger quantity of oil—6 to 10 per cent. The whole wheat has about 2 per cent., and bran, the refuse of the grain, as much as 4 to 5 per cent.

Another important constituent of flour is the mineral matter, nearly half of which consists of phosphoric acid. In the whole wheat this ash amounts to 1½ to 2 per cent., but the finest flour, such as that known as Austrian or Hungarian, has only ·3 to ·4, while ordinary home-made flour, not nearly so white in colour, although equally good to the taste, has from ¾ to 1 per cent. I consider the use of very fine flour to be a great mistake. All the constituents of the wheat are not only useful, but essential to the healthy development of the human body, and if the coarse bran only were removed, the remaining mixture would represent the perfection of flour for making bread. The mineral matter is as necessary as the gluten—our bony frame consists chiefly of phosphate of lime, the blood is rich in mineral salts, and no portion of the body, except perhaps the layers of fat with which some persons are

lined, contain more or less mineral matter. It is greatly to be regretted that the use of oatmeal is gradually dying out in Scotland, and is likely soon to be a matter of history. I am convinced that we would continue to be a stronger and more robust nation, if we ate more oatmeal porridge and less wheaten bread, especially fine white bread. In everything that tends to nutrition—gluten, oil, and mineral salts—oatmeal is superior to flour. There may be something in the assertion that the extensive use of oatmeal is inconsistent with the confinement, impure air, late hours, and generally artificial habits of town life; but those who are so fortunate as to enjoy the pleasures and advantages of the country would consult their interests by an extensive use of oatmeal in all its various forms. I can only allude very briefly to other kinds of grain. Indian corn meal resembles oatmeal very closely in composition, and, although not much used in this country, is a staple article of diet in America. I do not mean Indian corn flour, which is merely the starch made from the grain, and has no nutritive property apart from the milk with which it is cooked. Barley is also highly nutritious, and an excellent food, but contains less oil than oats or Indian corn. Rice contains only 7 per cent. of gluten, very little mineral matter (scarcely 1 per cent.), and a mere trace of oil. It is well adapted for the natives of hot climates, who do not require so much of the flesh-forming constituents, or oil, as those of colder countries; and, when used by us, it should be combined with fatty and nitrogenous substances, such as are found in milk and cream, or meat and rich gravy. Beans and peas are the antipodes of rice; they contain about 30 per cent. of gluten, a moderate proportion of fat, and a good amount of mineral salts. If cooked with fat of some kind, they form a food of a very sustaining character, in fact, "bacon and beans"

form a standard dish with the English working-classes, and they thrive on it about as well as our own peasantry do on oatmeal. Potatoes are first-rate food, if we can eat a large quantity of them, but there is not much nourishment to be derived from them otherwise. They contain only 2 per cent. of flesh-forming constituents, no fat, about 23 of starch, etc., and 75 of water. Turnips contain 80 to 90 per cent. of water, but the dry substance contains more gluten than that of the potato, and carrots have about 80 per cent. of water, and the dry substance contains an appropriate mixture of gluten, fat, and saccharine matter, with a sensible proportion of woody fibre.

I should say here that the two great articles of respiratory food, fat and starch (with which gum and sugar may be classed), are generally considered to be interchangeable; hence sugar is said to be fattening—but, whether or not starch or sugar is capable of being transformed into fat in the body, it is certain that, for keeping up the heat of the body, they are equally useful; but oil is, weight for weight, nearly two-and-a-half times more efficacious as a heat-producer than the members of the starch series.

We must now pass on to our next typical article of food—beef. The flesh of animals differs from the vegetable foods we have been studying, in that starch, sugar, and allied substances are absent; the only heat-producer being fat. On the other hand, the nitrogenous compounds in animal food have almost exactly the same composition as, and are practically identical with, the corresponding albuminoids found in the seeds, leaves, and tuberous roots of plants. In flesh there are two nitrogenous compounds, fibrin, which forms the solid basis of the meat, and albumen, which is contained in the juice, which may be pressed out by subjecting the beef to pressure,

or by digesting it with cold water. The fibrin, when thoroughly purified, is a white, stringy substance, quite devoid of taste. If the juice of meat is boiled, the albumen it contains becomes insoluble, just as in the case of the white of an egg, and if this is separated by filtration, and the clear liquid evaporated down nearly to dryness, we get a semi-solid mass containing the salts of the flesh, creatine, and various organic compounds, grouped under the general term "extractive matter." This is Liebig's extract of beef, which is invaluable for making beef-tea. This, I may here remark, is not a food in the ordinary sense of the word, although it contains some of the constituents of blood, and should rather be considered in the light of a stimulant, very useful in cases of sickness or convalescence, but scarcely suitable, or at all events unnecessary, for people in robust health. Beef-tea made in the ordinary way is different from Liebig's extract in that it contains the coagulated albumen, and generally also traces of fat. As a pure stimulant it is inferior to the extract, and approaches somewhat to the composition of an article of food, although in a rather attenuated condition. Beef-tea should be made from very lean beef, but of the juiciest description, and should be prepared in this way:—It is chopped up as fine as possible with a mincing knife, and then put into a small pan, with a sufficient quantity of cold water, and well stirred about with a spoon. It is now put over a slow fire and brought up to the boil, the whole process occupying, perhaps, fifteen to twenty minutes. If it is stirred during the whole time, so much the better. Whenever it comes to the boil it is ready for use, and should be poured off at once, and afterwards the fat should be carefully removed with a spoon. To return from this digression, I have to state that the fat of meat is a very

important constituent, and amounts to something like thirty per cent. on the average, while the variations are very great. Very lean meat is generally deficient in juice, and is consequently unsavoury, and although it contains a larger proportion of albuminous compounds than moderately fat meat, it is less likely to be beneficial to the human system, which demands a due admixture of the heat-producing with the flesh-forming constituents of food. A considerable amount of the fat is always lost in the cooking, and in spite of all precautions a pretty large proportion of the juice is also lost—as, for instance, in grilling steaks and chops. The cooking of meat is quite as important as the original quality—even more so, perhaps, for the best meat may be ruined by bad cooking, while a good cook will contrive somehow or other to make a presentable dish out of very unpromising materials. There is no nation under the sun that can boast of finer oxen and sheep than we have in Scotland, and probably none, in Europe at least, where the art of cooking is so much neglected. Unfortunately, I can only impart to you the very slight knowledge, and that theoretical rather than practical, that I possess—still it may be useful to some who know even less than I do.

There are three general methods pursued in this country:—1st, boiling; 2nd, stewing or baking; 3rd, roasting or frying. In all of these operations a considerable loss of weight occurs. For example, taking 4 lbs. of moderately fat beef or mutton, the

		lbs.	ozs.
4 lbs. Beef,	in boiling, lose, - - -	1	0
do.	in baking or stewing, -	1	3
do.	in roasting, - - -	1	5

		lbs.	ozs.
4 lbs. Mutton,	in boiling, lose, - -	0	14
do.	in baking or stewing, -	1	4
do.	in roasting, - - -	1	6

The loss is traceable to two distinct causes, the melting out of the fat and the exudation of the juice, and the evaporation of water. Meat may be cooked with the desire of retaining in it as much as possible of the juice, as in roasting and stewing; or it may be with the object of extracting as much as possible of the juice, so as to make a rich soup—the meat in this case being valueless or of secondary importance; or we may combine the two to some extent, as is common in Scotland—make a soup or broth, which contains a sufficient proportion of the juice of the meat to render it palatable, still leaving the greater proportion in the meat itself.

If we apply a sharp heat to a piece of fresh meat, the first effect is to cause the fibres to contract, so as to squeeze out a little of the juice, and to a certain extent to close up the pores and prevent the escape of the remainder; the second is to coagulate the albumen, and thus effectually and completely to plug up the orifices and retain within the meat all the internal liquid. After this, the cooking goes on simply by the conduction of heat from without inwards, in the case of boiled meat; but in roast meat, probably by the conversion of a part of the water into vapour, by which a kind of steaming is effected. Well-cooked meat, however prepared, should be full of its natural gravy. In roasting, it should be exposed to a quick fire at first, although, when the contraction of the fibres to which I have referred has taken place, it may be removed further from the source of heat. In grilling steak or chops, these should be placed over a hot and perfectly clear fire, and kept constantly turned over and over to prevent

them from being burnt. If properly done, the juice will almost spout out when the surface is pierced. In making soup, the meat should be cut thin and put on with cold water, and heated very gradually, as in making beef-tea. The boiled meat in this process will be vapid, hard, and unsavory, and although only one-eighth of the whole of the dry substance of the flesh is extracted, the remainder is almost uneatable. In preparing soups it is customary to prepare a "stock," by boiling certain parts of the animal, particularly that part of the leg called the hock, for many hours. Such soup, containing as it does a great amount of gelatine, is less wholesome and far less pleasant to the taste than that made as I have indicated from lean beef, and boiled only for a short time. But when meat is boiled to be eaten, an entirely different course should be pursued—the pot of water should be fully boiling before the meat is put in, and the boiling should be very brisk for ten minutes or so, but it may then be moderated, and the boiling may be continued gently until the meat is fully cooked. When the meat is first immersed in the boiling water, the outer part contracts, and the albumen at that place coagulates and prevents the egress of the juice from within, as well as the ingress of water from without. The more solid and compact the piece of meat, the more complete will be the preservation of the juice in the interior of the meat. When both meat and soup are to be taken as food, it is of less importance to preserve the juice—in fact, unless a portion of it is dissolved out, the soup will not be worth eating. In this case the meat may be cut solid, but may be put on with cold water, so that a compromise is effected, and both soup and meat are tolerably good.

I regret that I cannot on this occasion enter more fully into the subject of animal food, embracing, as it does, fowls, fish,

and eggs. A consideration of the matter, such as its importance deserves, would require a whole series of lectures, instead of a portion of a single discourse. We must now pass on to the preservation of food, which forms the concluding topic this evening.

THE PRESERVATION OF FOOD.

The reason for the introduction of methods of preserving food in primitive times was very obvious. A single family was unable to consume the whole of a carcase during the time it would, under ordinary circumstances, remain fresh; and unless it could be rendered in some way non-putrescible it would become useless. But the production of preserved food has now assumed enormous dimensions; being not only used extensively on board ship, but also supplying a large proportion of the food of the people. With regard to the importations from North America alone, I quote the following from a Glasgow paper of date 17th Dec., 1878:—"The import of live and dead meat from New York and Canada at the Clyde continues to increase, notwithstanding the extensive decline in almost every other article of import. During the month of November 389 live cattle and 784 live sheep were landed, as against no live oxen and only 547 live sheep landed in November, 1877. There were also 3977 quarters of fresh beef, and 701 carcases fresh mutton imported, as against 1883 quarters beef, and no mutton, in the corresponding month of last year. In addition to the above, there were also

landed in November last, 20,000 boxes of tinned meats, 8120 boxes bacon, 290 barrels salt pork, 1620 barrels salt beef, and 1278 tierces hams." The quantities imported into Liverpool are vastly greater, and, if we add the imports into London and other places from Australia, New Zealand, South America, and the Continent, the figures will be found to represent a large proportion of the whole meat supply of the country. The subject is therefore one of great interest and importance.

There are several leading methods of preserving articles of food—1st, by drying; 2nd, by the addition of preservative substances; 3rd, by sealing up so as to prevent contact of air; and 4th, by the application of cold. We shall consider these in order, but with a brevity consistent with the limited time at our disposal.

Preservation by Drying is practised both with animal and vegetable substances. Vegetables, and particularly potatoes, turnips, and carrots, are dried at a moderate heat, after being cut or sliced into thin pieces, and may thus be preserved in packets for years without loss of flavour or danger of spoiling. By soaking in cold water, they swell up to nearly their original bulk, and may then be cooked in the usual way. In making these preserved vegetables, it is essential to dry them at such a low heat that the vegetable albumen will not be coagulated. In the extensive salideros of the Rio de la Plata in South America, where oxen are killed chiefly for their hides and bones, a portion of the flesh is cut into thin strips, and hung up to dry in the sun, when it constitutes "jerked beef," and is sent to the West India Islands, Demerara, and adjacent countries, where it forms the principal animal food of the negro population. Milk evaporated in a vacuum pan to a syrupy or pasty consistence, and mixed with some cane-sugar,

will keep good for a long time, even if freely exposed to the air, and the same is the case with ordinary sugar, especially if it is not quite pure. A weak solution of sugar soon attracts germs from the air, and begins to ferment and become sour; but a strong syrup will keep perfectly fresh for months. Among other examples of preservation by simple desiccation, I may mention apples, meat biscuits, oatmeal cakes, rusks, and biscuits of various kinds. If these are kept perfectly dry they are practically indestructible.

Our second head—preservation by the addition of some substance of an antiseptic nature—is a comprehensive one. The most common antiseptic agent is common salt. The effects produced by the application of salt to meat are much the same as those observed when a quick heat is applied. The fibres contract, the bulk of the meat is decreased, and a portion of the juice is forcibly expelled, dissolving the salt and forming a fluid brine. It is said that as much as one-third of the whole of the juice is often forced out in this way, diminishing the natural flavour and the quantity of the soluble constituents. At the same time the pores of the meat are closed, thus preventing access of air, and diminishing the liability to decay; while there appears to be also a weak chemical combination of the fibrin with the salt, which does not readily decay. Again, it is tolerably certain that the germs which are constantly floating about in the air, and which play a most important part in the putrefaction of animal and vegetable substances, will not develop and fructify in a concentrated saline solution. In consequence of the loss of the soluble matters of the meat, which mix with the brine, salt beef and pork are less wholesome than fresh meat. Those who are condemned for months at a time to eat salt meat are subject to scurvy, which results from the

incapacity of the blood to form the solids of the body from deficiency of the necessary ingredients. Green vegetables, or those dried as I have described, are the natural antidotes to scurvy, but the usual preventive is lime or lemon juice, which is rich in mineral salts, and appears to supply the deficiency of these in the salted meat. Whether the citric acid, the principal constituent of the juice, is also useful, is a disputed point; but at all events it does not appear to do any harm. Salting is applied also to butter, to a small extent to cheese, and extensively to herrings.

Sugar has a similar effect to salt, and is used extensively in preserving fruits and in making jams and jellies.

Creosote, contained in the smoke of wood, is employed, along with partial drying, in the preservation of fish of various kinds, and of pork in the form of hams. Kippered herrings and Findon haddocks are familiar examples; but ling and codfish are simply salted and dried on the sea shore. Creosote coagulates the soluble albumen, thus closing up the pores; but the effect is chiefly due to the power of this interesting chemical compound of destroying the lower form of animal and vegetable life. The wood most commonly used is beech. Creosote may be obtained in a pure state by a somewhat tedious process, from wood tar, and coal tar yields an analogous compound—carbolic acid—which is used as an antiseptic in surgery, and, in its impure form, for preserving timber (especially for railway sleepers), for sheep-dipping compositions, dog soaps, &c.

Sulphurous acid and bisulphite of lime are valuable antiseptics, and are largely made use of. Lime and lemon juice are liquids which spoil very rapidly, but they are completely preserved by a very small addition of sulphurous acid in any form. The only preservative allowed by Act of Parliament or use in the merchant navy, however, is alcohol in the form

of rum, of which 15 per cent. must be added. A solution of bisulphite of lime is now used by butchers for brushing over pieces of meat which they wish to keep for some time, and for mixing with minced collops, to which it communicates a bright red colour. It is also used for preserving beer. Sulphurous acid is extensively used in sugar refineries. On the score of health there is no objection whatever to the use of sulphurous acid or its compounds.

Salacylic acid is used for preserving wines, beer, and other organic liquids, especially in Germany. It is a powerful preservative, but as yet it is very expensive. It is also used in medicine and surgery. It is closely allied to carbolic acid, although without its objectionable odour and taste.

The only other preservative I shall mention is boracic acid, which alone, or in combination with soda, is mixed with milk during hot weather with good effect. It is a mixture of the composition I have mentioned that is sold under the name of glacialine salt, and is much used by dairymen. It is perfectly harmless.

We now come to our third system, namely, preservation by excluding the air. The system almost universally employed is that invented by Mons. Apert, and by it every description of food may be preserved for almost an indefinite period. The food is cooked in the usual manner, it is then placed in canisters of tin-plate, upon which a cover is afterwards soldered. This cover has in it a very small orifice. The canisters are now placed in an iron trough filled with a saturated solution of chloride of calcium, which has a boiling point considerably higher than that of water, and bv heating this up by compressed steam, or an open fire, the water in the cans is made to boil briskly, and the escaping steam carries with it every trace of air. When the workman considers

that this has been attained, he dexterously with one hand cools the top of the canister with a wet sponge, while with the other he places a drop of solder on the orifice, whereby it becomes hermetically sealed. The canisters are now placed in the proving-room, where they remain two or three weeks, at a temperature the most favourable for putrefaction, 70° to 80°. If, while in this room, they become plump, and acquire a rather swollen appearance, there is good reason to suspect that the air has not been completely expelled, and that putrefaction is going on, while if there is an evident contraction, the cans are considered good and fit for sale. Canisters have been opened after being kept for many years, and found to be quite fresh.

Fryer's patented process is a striking illustration of the correctness of the germ theory of putrefaction. In Apert's method the sole aim is to get rid of every trace of oxygen, but in this the object to be attained is to destroy the germs in the tins or attached to the meat. The tins are simply filled with the raw meat and the lids soldered on, and they are then exposed to heat in a chloride of calcium bath until the meat is thoroughly cooked, the germs being at the same time destroyed. I have opened a tin prepared in this way three years previously, and found the meat to be perfectly preserved.

It only remains for me now to speak of the system now so much in vogue for importing meat from North America, that which secures immunity from decay or putrefaction by cooling to a temperature a little above freezing. A great many years ago a traveller in Siberia, while ascending one of the rivers, found the carcase of an extinct species of elephant (in other words, the mammoth) in a state of perfect preservation. It was probably at least a thousand years old; at all

events this animal was unknown in its living form to any nation that has left written records. Since this discovery several bodies of the mammoth, in good preservation, with the hair on, and free from the effects of putrefactive decay, have been found in Siberia. The inference is that animal substances, when frozen, are practically indestructible; and during the last few years the principle has been carried into practice in the importation of meat from America. The first application was in the Cunard and other Transatlantic steamers, each of which has its ice-chamber, which contains enough fresh meat to last the entire voyage, even during the hottest months of the year. But more recently certain steamers, and notably those of the Anchor Line, have had immense chambers fitted up to hold quarters of beef, and carcases of sheep, and connected with them compartments to store a large quantiy of ice. By means of steam power air was withdrawn from the ice-chamber and sent into the meat-chamber, and the latter was kept constantly at a temperature of 35° to 40° which was found to be quite as effectual in preserving the meat as freezing, which deteriorates somewhat the quality of the meat. In a particular case, which I give as an example, the steamer Ethiopia, one of the Anchor Line, has a meat-chamber capacity of 312 tons, of which 220 tons measurement is available for holding meat, while 92 tons measurement are occupied by the ice. In one case at least, owing to stress of weather, the supply of ice went done, and the whole of the meat had to be thrown overboard. There is thus not only a large outlay for ice, but from twenty to thirty per cent. of the available space is occupied by it; and if the vessel is detained a few days longer on the voyage than ice is provided for, the whole cargo has to be sacrificed. One other disadvantage attends this system of importing meat:

when the air is cooled moisture is deposited upon the carcase, which, on being removed from the chamber, is clammy and damp, and the meat does not keep many days. Notwithstanding these considerable disadvantages, the trade in ice-preserved meat is one that has of late assumed enormous proportions. During the nine months up to the 30th September last, the quantity imported into this country from America amounted to nearly 40,000,000 lbs., entailing a payment for freight of about £90,000, or at the rate of £120,000 per annum.

The process recently patented by Messrs. Bell and Coleman has for its objects the substitution of mechanical cooling for ice, and the drying of the refrigerated air, so as to maintain the meat in a natural condition. In a large experiment made in an apparatus erected at Messrs. Henderson's engine-works, the process has been conducted with highly satisfactory results. The chamber, which I have had the pleasure of inspecting when filled with meat, is 43 feet long, 29 feet broad, and nearly 11 feet high, and although not exactly of the same shape, it is of the capacity of 312 tons measurement. In two distinct experiments, extending, the one for 14 and the other for 28 days, the carcases were removed in perfect condition, and with all the appearance of meat about 2 or 3 days old. It would take too long to describe the somewhat complicated machinery used for cooling the air, but the space occupied is very much less than in the case of ice—only 5 per cent. of the total measurement—so that out of 312 tons carrying capacity, no less than 297 tons are available for cargo instead of 220 in the case of ice. Besides, the cost of cooling is immensely less than it is when ice is used. It is tolerably certain that, by this splendid invention, fresh meat may be brought from Australia, New Zealand, and the River Plate settlements,

although it will probably require to be actually frozen for such long voyages; and we cannot doubt that both the mother country and the colonies will be immensely benefited by the trade that will thus be established.

Ladies and Gentlemen,—I am reluctantly compelled to conclude this lecture as well as the brief course which I have undertaken to deliver. I feel that if I had had more time, I could have done the important subjects I have taken up more justice. I cannot hope to have accomplished more than to stimulate inquiry, and if I have succeeded in this, I shall be satisfied with the results of my labour. I now thank you for your kind attention. I ask you to forgive all imperfections, and to believe that, if I have not succeeded in doing justice to the topics discussed in these lectures, it is my misfortune rather than my fault.